Descriptive Catalogue

OF THE

GEOLOGICAL COLLECTION

IN THE

CHAMBERS INSTITUTION
PEEBLES

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BY

RICHARD TURNER
O.B.E., M.B., F.R.S.E.

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PREFACE

THE purpose of this Catalogue is twofold.

(*a*) To render as complete as possible, from an educational point of view, the Geological Collection in the Chambers Institution, Peebles.

(*b*) To render as simple as possible, by explanation of terms employed and by discarding unnecessary scientific detail, the classification and description of the various items exhibited.

This work is not intended for geologists. The objective is to help those who are interested in this collection, and in geology generally, but who are not sufficiently familiar with the principles of this branch of natural science to follow its systematic arrangement.

I desire to acknowledge gratefully the valued help I have received from the Royal Scottish Museum, and from the Geological Survey, Edinburgh, in regard both to classification of, and contributions to, the Geological Collection in the Chambers Institution. Also I wish to express my indebtedness to Mr S. S. Buckman for his able help in arranging the Ammonites, and to Mr Duncan, late Royal Scottish Museum, for valuable assistance in many ways.

RICHARD TURNER.

CHAMBERS INSTITUTION, PEEBLES,
May 1927.

INTRODUCTION

The Geological Collection in the Chambers Institution was begun by Dr W. Chambers in 1859, when the Institution was opened. It was a group of economic rocks and some fossils from the County of Peebles, consisting chiefly of sandstones, slates, limestones, etc.

This collection was gradually increased by many and varied contributions of which the following are the principal, viz. :—

A series of Old Red Sandstone specimens from Nairnshire. Presented by Professor Veitch, 1859.

A case of geological specimens from the Isle of Wight. Presented by Mrs W. Chambers, 1861.

A series of Ammonites and Belemnites from Whitby. Presented by Mr J. M'Lean, 1863.

A case of Devonshire fossils. Presented by the Baroness Burdett Coutts, 1871.

A series of economic rocks from the Department of Mines, New South Wales. Presented by Mr J. Lawrie, 1888.

A series of economic rocks from South Africa. Presented by Mr J. Clark, 1896.

Geological Collection of the late Rev. G. Gunn. Presented by Dr Gunn, 1913.

In 1921, when the various items were sorted out and assembled in series, there were many large gaps to be filled. To bridge over these gaps and render the series more complete the Royal Scottish Museum contributed liberally in regard to minerals, the Geological Survey in the matter of rocks, and the author added his own collection of rocks and minerals to help in this work.

On behalf of the Department of Mines, Ontario, Canada, a series of economic rocks from the Province of Ontario was presented by the Hon. Mr Justice Hodgins, 1926.

There is now a good representative collection arranged in three divisions as follows :—

I. Petrology or Rocks. II. Mineralogy or Minerals. III. Palæontology or Fossils.

FOREWORD

The Descriptive Catalogue of the Geological Collection in the Chambers Institution, Peebles, is of great educational value. Dr Turner has spent several years in preparing materials for this publication, and has made a special effort to convey the information in a form intelligible to those who have no elementary knowledge of geology. His ideal has been successfully achieved. The Collection has thus been made more attractive and instructive.

The Catalogue clearly illustrates two of the essential features of nature study—scientific order and thoroughness of method—which are valuable lessons for daily life. Dr Turner has rendered a great service to the community of Peebles and the surrounding district.

JOHN HORNE, LL.D., F.R.S.

20 Merchiston Gardens,
Edinburgh,
April 1927.

CONTENTS

PART I—PETROLOGY

PART II—MINERALOGY

PART III—PALÆONTOLOGY

GEOLOGICAL COLLECTION

Specimens marked with an asterisk were presented by the Royal Scottish Museum, Edinburgh

PART I—PETROLOGY

CHAPTER I

Rock-forming Minerals. Case A

Petrology—from the Greek *petra*, a rock, +*logos*, a discourse. That part of geology which treats of the relations, the structure, and the composition of rocks is termed petrology.

The principal rock-forming minerals are here described in regard to their rock-forming properties ; their economic and other qualities are considered under Part II—Mineralogy.

In our study of petrology we must first have some idea of what a mineral is, and what a rock is.

It is very difficult to define accurately the nature of a mineral so as to be satisfactory from all points of view, but as we are dealing with petrology we may define minerals as 'the constituent parts of which rocks are composed, possessing certain essential characters which are constant and which are characteristic of and peculiar to each kind of constituent. Such constituent parts are called minerals ; and a rock is an aggregate of such minerals.' A mineral therefore is something definite in regard to chemical composition, form, and so forth ; whereas a rock varies in character with the diversity and relative proportion of the minerals of which it is composed.

The rock-forming minerals crystallise in various forms, and according to their different degrees of symmetry they can be grouped into seven distinct systems of crystallisation. Each system has an imaginary set of axes of reference called the Crystallographic Axes, and the systems are defined according to

the relative lengths and the angles of inclination in this set of axes. These systems are :—

(1) **Cubic system**—three axes all at right angles to one another, and all of equal length.

(2) **Tetragonal system**—three axes all at right angles to each other, two being equal in length and one either longer or shorter.

(3) **Orthorhombic system**—three axes at right angles to each other, and all of unequal lengths.

(4) **Monoclinic system**—two axes inclined to each other but at right angles to a third axis, and all unequal in length.

(5) **Triclinic system**—three axes all inclined at oblique angles and all of unequal lengths.

(6) **Rhombohedral system**—three equal axes all inclined at the same angles but not at right angles.

(7) **Hexagonal system**—three equal axes mutually inclined to one another in one plane, and a fourth axis of different length perpendicular to this plane.

All crystals can be referred to one or other of these seven systems.

In our collection the principal rock-forming minerals and rocks are contained in the cases marked A, B, C, D, E, F, G. in the centre and at the end of the room.

Before commencing a description of the rocks it is essential that we should know something of the minerals which compose them, so that we shall begin with the rock-forming minerals.

These minerals are exhibited in Case A under their respective group names and species names, and in sequence in regard to description. They are primarily roughly divided into two classes, viz. (1) those minerals which are comparatively light in colour and light in weight, called the Leucocratic minerals—from the Greek *leukos*, white, +*kratos*, dominance ; (2) those minerals which are comparatively dark in colour and heavy in weight, termed Melanocratic minerals—from the Greek *melan*, black, +*kratos*, dominance.

The white-coloured or leucocratic minerals are again subdivided into three groups, viz. (1) QUARTZ. (2) FELSPAR. (3) FELSPATHOID. The dark-coloured or melanocratic minerals are also subdivided into the following groups, viz. (1) MICA. (2) AMPHIBOLE. (3) PYROXENE. (4) IRON ORE. (5) OLIVINE. (6) APATITE. (7) GARNET. (8) TOPAZ. (9) ZIRCON. (10) TOURMALINE. (11) SPHENE.

The following table represents the grouping :—

ROCK-FORMING MINERALS	Leucocratic or light-coloured	Quartz. Felspar. Felspathoid.
	Melanocratic or dark-coloured	Mica. Amphibole. Pyroxene. Iron Ores. Olivine. Apatite. Garnet. Topaz. Zircon. Tourmaline. Sphene.

The hardness of minerals varies in degree, and it is often useful in differentiating between them. The following is the recognised scale of hardness :—

1. Consistence of	Talc.	6. Consistence of	Orthoclase.
2. ,,	Gypsum.	7. ,,	Quartz.
3. ,,	Calcite.	8. ,,	Topaz.
4. ,,	Fluor Spar.	9. ,,	Corundum.
5. ,,	Apatite.	10. ,,	Diamond.

Nos. 1 and 2 can be scratched with the finger-nail ; 3, 4, 5, and 6 can be scratched with a knife, but 6 with difficulty ; 7, 8, 9, and 10 cannot be scratched with a knife, but 8 will scratch 7, 9 will scratch 8, and 10 will scratch 9.

Minerals also vary in weight, and the specific gravity (usually written sp. gr.) or density of a mineral is its weight when compared with the weight of an equal volume of distilled water at the temperature of 39·2° Fahrenheit which is reckoned unity.

We are now in a position to begin the description of the various rock-forming minerals, and we shall follow the series as they are classified in Case A.

I. QUARTZ GROUP. This name is probably derived from the German *Quarz*.

Quartz, which has the chemical formula SiO_2, is pure silica—the dioxide of the non-metallic element silicon. It is one of the most abundant, the most widely distributed, and the most

important of the rock-forming minerals. When pure it is colourless, water-clear, and transparent like glass, as in rock crystal; but when it contains impurities it varies in colour and degree of transparency from dark and opaque in cairngorm to pale rose colour in rose quartz. In its normal development quartz crystallises in beautiful six-sided prisms capped by six-sided pyramids. In rocks the crystals are usually very imperfect and frequently form a compact mass without obvious crystalline structure. It is very hard, being 7 in the scale of hardness; it cannot be scratched with a knife, and it can scratch glass. Quartz is unattacked by acids except hydrofluoric acid, and it is insoluble in alkalies which distinguishes it from opal. When quartz is broken there is no cleavage or smooth even surface, but there is a shell-like or conchoidal fracture which is bright and vitreous in character. Quartz is not a heavy mineral; the sp. gr. is 2·65, or about two and a half times as heavy as an equal volume of water. The prism faces of the crystal are always more or less striated or grooved horizontally—that is, the faces are marked by fine lines perpendicular to their edges.

Case A

The following specimens are exhibited in the case :—

(*a*) **Quartz crystals**—six-sided prisms capped by six-sided pyramids, clear and colourless, with striations perpendicular to the edge of the prism. These are specimens of rock crystal, so called from the ancient belief that they were pieces of ice frozen so hard that they could not be thawed. The name crystal is derived from the Greek word *krystallos*, which means 'clear ice.'

(*b*) **Quartz crystals**—dark-coloured and opaque as seen in the cairngorm crystals.

(*c*) **Quartz**—rose-coloured and amethyst as exemplified in the rose quartz and amethyst quartz specimens.

(*d*) **Quartz**—in which there is no obvious crystalline structure.

II. Felspar Group. *Felspar*—derived from the German *Feldspath.*

This is a group of very important and very widely distributed rock-forming minerals, which are primary constituents of most of the eruptive rocks. They resemble each other in chemical

composition and in crystalline form. They are silicates of alumina with either potash, soda, or lime, so that chemically we get three different kinds of felspars, viz. potash felspars, soda felspars, and lime felspars.

When pure the felspars are white or colourless ; when they include impurities they are usually reddish or grey. Sometimes they are transparent and glassy, but as they are met with in rocks they are generally dull and somewhat opaque. There is good cleavage in two directions which is characteristic of all felspars. In some the cleavage planes are at right angles to one another, and in others the cleavage planes are oblique. Hence we get a natural grouping of felspars into two systems of crystallisation according to their angles of cleavage, viz. :—

(1) **Monoclinic system.** The cleavage planes are at right angles to one another, and the crystals possess only one plane of symmetry. *The orthoclase series.*

(2) **Anorthic or Triclinic system.** The cleavage planes are oblique and not at right angles. In this system the crystals have no planes of symmetry. *The plagioclase series.*

Those felspars whose cleavage planes are at right angles to one another are termed orthoclase—from the Greek words *orthos*, straight, +*klasis*, fracture—hence breaking or fracturing at right angles.

The felspars having their cleavage planes oblique or not at right angles are termed plagioclase—from the Greek *plagios*, oblique, +*klasis*, fracture—hence breaking obliquely.

The following is a grouping of the felspars :—

FELSPARS

Monoclinic System.	Anorthic System.
Right-angled Cleavage.	Oblique-angled Cleavage.
Orthoclase Series.	Plagioclase Series.
Potash Felspars.	Soda-lime Felspars.

Microcline is a potash felspar, but it crystallises in the anorthic system.

When two crystals grow together in such a definite manner that

the one appears the mirror reflection of the other it is called a twinned crystal. This twinning is common in felspars, and especially in the plagioclases where the repeated twinning forms fine parallel striations on the cleavage surface, which in hand specimens can often be seen with the naked eye, or with the aid of a pocket lens.

All felspars possess approximately the same degree of hardness which is number 6 in the scale, and therefore with difficulty they can be scratched with a knife. Like quartz they are not very heavy minerals; the specific gravity varies from 2·55 to 2·75, being little more than two and a half times as heavy as an equal volume of water.

The following specimens are arranged and named in Case A under the group name Felspars.

1. Orthoclase Series . . . { Orthoclase. Sanidine. Microcline.

(*a*) **Orthoclase**—reddish-coloured and white specimens.

This mineral is a potash felspar and crystallises in the monoclinic system. Probably it is the most abundant of the felspars, and as an important rock-constituent it is found in granites, syenites, and some other igneous rocks, especially those which also contain quartz. Veins of pegmatite associated with masses of granite consist largely of coarse crystalline orthoclase. Pegmatite —from the Greek *pegma*, a framework—a name formerly given to masses of granite usually found in veins, consisting of intergrowths of quartz and orthoclase—Graphic Granite.

Orthoclase crystals found in igneous rocks are generally imperfectly developed and have a dull, chalky or stony appearance. Among the sedimentary formations it occurs in arkose rocks which are derived chiefly from the disintegration of granite and gneiss.

(*b*) **Sanidine**—from the Greek *sanis*, *sanidos*, a board—tablet form.

In every respect this potash felspar resembles orthoclase, but it looks more glassy; it is more transparent and usually much cracked. It often occurs in tabular form, and also as small prisms or irregular grains in some of the more recent acid lavas.

(*c*) **Microcline**—derived from the Greek *mikros*, small, +*klinein*, to incline—referring to the angle between the two cleavage surfaces 89° 30′, being little short of a right angle.

Another potash felspar which has the same chemical com-

position as orthoclase, though it crystallises in the anorthic (triclinic) system of crystallisation, whereas orthoclase crystallises in the monoclinic system. These two minerals may be considered as dimorphic forms of potash felspars. Dimorphic—from the Greek *di*, double, +*morphe*, form—applied to minerals which, having the same chemical composition, crystallise in two different forms. Orthoclase and microcline occur naturally as constituents of granite and pegmatite. In external appearance their crystals are so much alike that they can only be distinguished by optical examination.

2. PLAGIOCLASE SERIES . . . $\begin{cases}\text{Albite.}\\ \text{Oligoclase.}\\ \text{Labradorite.}\\ \text{Anorthite.}\end{cases}$

The plagioclase felspars are among the most important rock-forming minerals. They form an isomorphous series. Isomorphous—from the Greek *isos*, like, +*morphe*, form—having a like form. They are primary constituents of many eruptive rocks and they are widely distributed among crystalline schists. In Case A will be found representatives of the series classified and named under their group name felspars and species name plagioclase.

(*a*) **Albite**—so called from the white colour of its crystals—from the Latin *albus*, white.

Albite is a soda felspar and forms one of a continuous series of soda-lime plagioclases ranging from albite at the alkali end to anorthite at the basic end of the series. It is frequently met with as lamellar intergrowths in orthoclase as in perthite; it is also found in certain crystalline schists. Hydrochloric acid has no effect upon albite.

(*b*) **Oligoclase**—from the Greek *oligos*, little, +*klasis*, a breaking or fracture—because this mineral was supposed to have a less perfect cleavage than albite.

Oligoclase is an intermediate member of the plagioclase series. It consists of a mixture of soda felspar and lime felspar with the soda felspar in excess. Some crystals of oligoclase have a beautiful metallic reflection due to the inclusion of small scales of hematite. It is frequently met with in eruptive rocks as in syenites, diorites, and many porphyries, and also in some of the crystalline schistose rocks. It is not attacked by hydrochloric acid.

(*c*) **Labradorite**—derived from the place-name *Labrador*, where it occurs in some rocks in large masses as in the coarse-grained norite of Labrador.

Here is another intermediate member of the plagioclase series. In composition it is more basic than oligoclase and consists of soda and lime felspars with the lime felspar in excess. It is a primary constituent of some basic eruptive rocks such as gabbro, dolerite, and basalt. Frequently there is a fine iridescent display of colours due to the inclusion of minute scales of other minerals along the cleavage surface. Labradorite is slightly affected by hydrochloric acid.

(*d*) **Anorthite**—derived from the Greek *an*, not, + *orthos*, straight—the mineral whose angles are not straight or right angles.

Anorthite is a lime felspar and finds its place at the basic end of the plagioclase series. It occurs as a constituent of many basic igneous rocks, as gabbro, basalt, etc. Anorthite is decomposed by hydrochloric acid with the separation of gelatinous silica.

In the plagioclase series fine striations may be seen along the cleavage planes due to twinning, and this appearance becomes very characteristic of the series as seen in sections of these minerals examined microscopically in polarised light. Fusibility is greatest in albite, and decreases with the diminution of soda and the increase of lime. The sp. gr. is least at the soda end and greatest at the lime end of the series.

III. Felspathoid Group . . . $\begin{cases} \text{Leucite.} \\ \text{Nepheline.} \\ \text{Sodalite.} \\ \text{Haüyne.} \end{cases}$

The felspathoids—from *felspath* with the suffix *oid*—resemble the felspars in chemical composition, being silicates of alumina with either potash or soda, but they differ from them in crystalline form. As rock-formers they are not so important as the felspars, and the rocks of which they are constituents are not very widely distributed. As a rule they are restricted to a few igneous rocks belonging to a comparatively late geological period. In Case A they are arranged and named under the group name Felspathoids.

(*a*) **Leucite**—derived from the Greek *leukos*, white—from its whitish or ash-grey colour.

Leucite is a silicate of alumina and potash. This mineral crystallises in well-defined single crystals with twenty-four faces or

surfaces, similar in form to the crystal garnet. This form of crystal is called an icositetrahedron—from the Greek *eikosi*, twenty, +*tetra*. four, +*hedra*, a seat or base —a crystal with twenty-four faces.

When pure it is transparent and colourless, and when it contains impurities it is generally whitish, ash-grey, or greyish yellow in colour. The hardness is between 5·5 and 6 in the scale, and the sp. gr. is about 2·5. Hydrochloric acid decomposes it slowly with the separation of silica. Leucite is not a very stable compound and often becomes altered into zeolites. Zeolite—from the Greek *zeein*, to boil, +*lithos*, a stone. The zeolites contain a quantity of water, and when the blowpipe is applied to them they swell up with the steam from the water which is thus driven off. As a rock constituent leucite occurs in several basic Vesuvian lavas.

(*b*) **Nepheline**—from the Greek *nephele*, a cloud. When a clear crystal of nepheline is immersed in acid it becomes cloudy, hence the name.

This mineral is a silicate of alumina and soda which crystallises in stout hexagonal prisms. Hexagonal—from the Greek *hex*, six, +*gonia*, an angle -a prism with six angles and six sides. The crystals have a glassy lustre and are clear or white in colour. They dissolve in hydrochloric acid with the separation of gelatinous silica. The hardness and sp. gr. are much the same as in leucite, and, like the leucite crystals, they are unstable and frequently alter into zeolites. Nepheline is found as a constituent of phonolite and some basalts. Phonolite—from the Greek *phone*, sound, +*lithos*, a stone—so named from the peculiar metallic clinking sound when the rock is struck with a hammer ; hence also known as clinkstone.

(*c*) **Sodalite**—so named because it contains *soda*.

Sodalite is another silicate of alumina and soda which crystallises in dodecahedra of the isometric system. Isometric—from the Greek *isos*, equal, +*metron*, a measure, and dodecahedra —from *dodeka*, twelve, +*hedra*, a base—hence a crystal with twelve equal sides or faces.

The crystals are sometimes clear and glassy, as found in some of the lavas of Monte Somma, Vesuvius ; another form of it is blue in colour and found in masses in a kind of syenite called sodalite-syenite. It is also a constituent of some effusive rocks. Like other felspathoids it is not very stable and tends to alter into fibrous zeolites. Hydrochloric acid decomposes it into a gelatinous silica.

(*d*) **Haüyne**—named after *R. J. Haüy*, French mineralogist.

Haüyne has a complicated chemical formula and is a silicate of alumina with soda, lime, and a small quantity of sulphur. Like sodalite it crystallises in the isometric dodecahedral system with twelve equal sides or faces. It is usually blue or bluish-green in colour, and it occurs as a constituent of phonolite and other igneous rocks rich in alkalies. Like other members of this series it frequently decomposes into more stable compounds. Hydrochloric acid alters it readily. All the felspathoids resemble each other closely in regard to hardness, sp. gr., and the manner in which they deteriorate.

IV. MICA GROUP . . . . {Muscovite. Biotite.

Mica—probably derived from the Latin *micare*, to shine or glitter.

The members of the mica group are important and widely distributed as rock-forming minerals. They possess a perfect cleavage, giving broad flat surfaces from which elastic, flexible, and tough flakes can be split off to almost any thinness. They crystallise in the monoclinic system, and the crystals usually form hexagonal or rhomb-shaped scales or plates. Rhomb—from the Greek *rhombos*, a rhomb, which is a figure with four equal sides ; the opposite sides are parallel, but the angles are not right angles ; it is diamond-shaped.

The various kinds of mica range in colour from water-clear and transparent to black and opaque, and they possess a lustre varying from pearly to submetallic on the cleavage surfaces. The sp. gr. varies from 2·7 to 3·1 in the different species, and the hardness is from 2 to 3 in the scale. The smooth cleavage planes can be scratched with the finger-nail.

(*a*) **Muscovite**—sometimes called potash or white mica.

This mineral is a silicate of aluminium and potassium. It is usually pale-coloured or silvery, but sometimes it is colourless and transparent. It is not affected by hydrochloric acid. As a primary rock-former it is chiefly associated with granites and crystalline schistose rocks—schistose from the Greek *schizein*, to split—rocks that split into bands or folia.

It is not readily decomposed, and it is therefore frequently met with in the form of small shining plates or scales in many of the sedimentary rocks. Muscovite is derived from the old term

Muscovy Glass, which was clear mica used instead of glass for windows in Russia.

(*b*) **Biotite**—sometimes called black mica—named after the French physicist, *J. B. Biot.*

Biotite, besides being a silicate of alumina and potash, contains also magnesium and iron, so that it is a ferro-magnesian mica. It varies in colour from dark-brown or green to black, though not infrequently it assumes a paler colour through loss of iron. Hot hydrochloric acid decomposes it. It is a primary constituent of some granites, syenites, and diorites. As biotite is a less stable compound than muscovite, it is met with less frequently in sedimentary rocks.

V. Amphibole Group . . . $\begin{cases} \text{Hornblende.} \\ \text{Actinolite.} \\ \text{Tremolite.} \\ \text{Asbestos.} \end{cases}$

Amphibole—from the Greek *amphibolos*, ambiguous or deceptive—a term applied by R. J. Haüy to include hornblende, actinolite, and tremolite, but it is now used as a group name for the hornblende family.

The amphiboles form another group of important rock-forming minerals, and chemically they are silicates of magnesium, calcium, and iron with or without aluminium. As a rule they are dark-coloured, though this varies, and they crystallise in prisms with a tendency in some cases to assume fibrous or radiating forms. Their sp. gr. ranges from 2·9 to 3·5, and the hardness varies from 5 to 6 in the scale. All the members of the group mentioned here form an isomorphous group (similar in form), and crystallise in the monoclinic system. They are not attacked by acids.

(*a*) **Hornblende**—from the German *horn*, horn, + *blende*; in reference first to its toughness and secondly to its worthlessness as an ore. German *blind*, blind, hence deceptive or valueless.

Hornblende, the most important member of the amphibole group, is a silicate of iron, magnesium, aluminium, and calcium. In colour it is dark-green to black, and occurs generally in elongated prismatic crystals. Sometimes, however, the crystals are blade-like, fibrous, or in radiating groups. This mineral has good cleavage in two directions, with an angle greater than a right angle at the junction of the cleavage planes—an angle of about 124°.

Hornblende is an essential constituent in syenites, diorites, and some granites ; it is also found in many of the crystalline schistose rocks.

(*b*) **Actinolite**—from the Greek *aktis*, *aktinos*, a ray, +*lithos*, a stone—the ray stone or the stone with radiating crystals.

This mineral, besides being a silicate of calcium and magnesium, contains a small amount of iron, and to this is due its characteristic green colour. The crystals are often bladed or needle-like, and it is a common constituent of many crystalline schistose rocks. Occasionally it is met with as an alteration product in igneous rocks, as in some gabbros.

(*c*) **Tremolite**—so named from *Tremola* in Switzerland where good specimens are found embedded in crystalline limestone.

Chemically tremolite is a silicate of calcium and magnesium. In colour it is white, grey, or very pale-green, hence sometimes it is called white amphibole. The crystals are long, flattened, and blade-shaped, with longitudinal striation ; or they form fine fibrous aggregates radiating from a centre. They possess a pearly or silky lustre. Tremolite is a constituent of some of the schistose rocks, and it is also found embedded in crystalline limestone near the area of contact with eruptive rocks as at Tremola in Switzerland.

(*d*) **Asbestos**—from the Greek *asbestos*, unquenchable or incombustible—in allusion to its power of resisting fire.

In crystalline form and chemical composition this mineral is identical with actinolite and tremolite. The crystals are long, prismatic, and so fine that they are quite flexible. In fact, when actinolite and tremolite assume crystalline forms so fine and fibrous that they can be teased out into long, soft, silky threads they are known as asbestos. The colour varies from white to green according to the source of origin—tremolite or actinolite.

VI. Pyroxene Group . . . { Augite. Diallage. Hypersthene. Enstatite.

The term pyroxene is derived from the Greek *pyr*, fire, +*xenos*, a stranger—hence not belonging to, or a stranger to the fiery or igneous rocks. It was first applied by R. J. Haüy to the black crystals of augite which he found in the lavas of Vesuvius and Etna, as he thought these black crystals were not developed in the

lavas, but caught up by them and retained in them. Pyroxene is now used as a group name for the augite family.

The members of this group in many respects resemble those of the amphibole group. Their chemical formulæ are much the same, and they crystallise in similar types. In the case of the pyroxenes the cleavage in two directions is not quite so marked as in the amphiboles, and the angle between the cleavage planes is nearly a right angle—87°, whereas in the amphiboles it is greater than a right angle—124°. They crystallise in eight-sided prisms of the monoclinic and rhombic systems. Acids have no effect upon them.

The pyroxenes are silicates of magnesium, calcium, and iron, and they may or may not contain aluminium. The colour generally is dark; the hardness is about 6 in the scale, and the sp. gr. is something between 3·1 and 3·6.

(*a*) **Augite**—from the Greek *auge*, lustre—from its black shiny appearance.

This mineral crystallises in the monoclinic system and is one of the pyroxenes which contains aluminium. The crystals are short, stout, dark-coloured, greenish-brown to black prisms which are sometimes twinned. Augite is an essential constituent in dolerites and basalts, and as an accessory constituent it is widely distributed in other eruptive rocks.

(*b*) **Diallage**—from the Greek *diallage*, change or difference—alluding to different cleavages and planes of fracture as used formerly by R. J. Haüy.

Diallage is a brownish, greenish variety of augite which has a foliated or lamellar structure. The faces of this lamination or pseudo-cleavage have a pearly or submetallic lustre due to the inclusion of minute plates or rods along the cleavage surface. Diallage is a primary constituent of gabbro and occurs as an occasional ingredient in serpentine and olivine rocks.

(*c*) **Hypersthene**—from the Greek *hyper*, over, +*sthenos*. strength, hence tougher—so called to distinguish it from hornblende with which it was often confused.

Hypersthene is one of the rhombic pyroxenes and is a ferro-magnesian silicate of brownish-black colour. Isolated well-developed crystals are very rare. It is usually found in foliated masses in basic igneous rocks, of which it forms a primary con-

stituent as in Labrador norite. Frequently its surfaces show a display of coppery, reddish reflections due to numerous small platy inclusions.

(*d*) **Enstatite**—first described by G. A. Kenngott and named by him enstatite—from the Greek *enstates*, an opponent—alluding to the difficulty with which it is fused with the blowpipe.

We have here another rhombic pyroxene. In colour it is white, greyish, or brownish, and is a silicate of magnesium. Sometimes it contains a little iron which replaces part of the magnesium. Isolated crystals are not very common, and the mineral is usually found as a constituent of basic igneous rocks, either as masses in plutonic rocks and serpentines, or as small crystals or grains in volcanic rocks. The specimen in the case is in the form of a vein.

VII. Iron Ore Group . . . { Hematite. Magnetite. Ilmenite. Limonite. Pyrites.

The iron compounds are widely distributed and occur as accessory constituents in many igneous rocks. They are either oxides or sulphides of iron.

(*a*) **Hematite**—from the Greek *haima*, blood—the bloodstone of the Greeks, so named from its colour resembling dried blood.

Hematite is the ferric or sesquioxide of iron having the chemical formula Fe_2O_3. It has a sp. gr. of 5·19 to 5·28, and the hardness is between 5·5 and 6·5 in the scale. Hematite is found in two varieties, viz. in the massive form and in the crystalline. The two varieties differ much in external appearance, but they both yield a characteristic reddish powder when scratched with a knife. The massive form is dull red in colour and is often found in rounded, nodular masses called ' kidney iron ore ' from the shape of the mass. Such masses may be soft, earthy, and reddish ; or they may be hard, compact, and dark. The crystalline variety is dark steel-grey to black in colour, and it crystallises in the rhombohedral system. It has a brilliant metallic lustre and it is known as specular iron ore, or iron glance. The specimens in the case illustrate the two varieties.

(*b*) **Magnetite**—so named from its *magnetism*—it is always strongly magnetic.

An oxide of iron having the chemical formula Fe_3O_4, magnetite is a combination of ferric oxide, Fe_2O_3, and ferrous oxide, FeO. It crystallises in the octahedral form, but crystals are not very common and they are decomposed by hydrochloric acid. It is generally found in compact or granular masses which are dull, black, and heavy ; or again, as minute octahedral grains or particles in many igneous rocks. These masses give a black streak or black powder when scratched with a knife, and this, together with their magnetism, is sufficient to distinguish them from other minerals. Magnetite is widely distributed as a rock-forming mineral and occurs frequently in schists and other foliated rocks, while it is not uncommon in many of the basic rocks. It is a stable compound and often appears in alluvial sands derived from the disintegration of those basic rocks in which it is found.

(*c*) **Ilmenite**—named from the *Ilmen Mountains* in the Southern Urals, whence come the best crystals of the mineral.

Here is another oxide of iron which also contains titanium (one of the metal elements). It has the chemical formula $FeTiO_3$ and is sometimes known as titanic iron. The crystals are rhomboid in form, dark or black in colour, with a metallic or submetallic lustre. The hardness is between 5 and 6 in the scale, and the sp. gr. from 4·56 to 5·21. When scratched with a knife it gives a black or very dark-brown streak or powder. Ilmenite generally occurs in massive form, and it is often met with widely diffused in many of the eruptive rocks and crystalline schists. This mineral is also found as a dark, black-coloured sand in some streams. A similar sand occurs in the *Iser Mountains*, Bohemia, hence the name *iserine* applied to it.

(*d*) **Limonite**—from the Greek *leimon*, a meadow—alluding to its occurrence as bog iron in meadows and marshes.

In this specimen we have an oxide of iron in the hydrated form —a ferric hydrate—having the chemical formula $2Fe_2O_3.3H_2O$, sometimes called the hydrated sesquioxide of iron. It is derived from the disintegration of other rocks containing iron. In structure it is either fibrous or microcrystalline, but it never assumes definite crystalline form. Limonite generally occurs in concretions or masses, often reniform or botryoidal in shape. Reniform—from the Latin *ren*, a kidney, +*forma*, form—hence kidney form or shape. Botryoidal—from the Greek *botrys*, a

bunch of grapes, +*eidos*, form—hence like a bunch of grapes. In colour it ranges from brown to yellowish brown; the streak of powder is brownish, so that it is occasionally referred to as brown hematite. The hardness is about 5 in the scale, and sp. gr. varies from 3·5 to 4. As a rock constituent it is always an alteration product.

(*e*) **Pyrite or Pyrites**—from the Greek *pyrites*, a stone that strikes fire—alluding to the sparks produced by striking the mineral firmly.

Pyrites is a combination of iron and sulphur—a disulphide of iron—and it has a chemical formula FeS_2. It crystallises in beautiful pale brass-yellow crystals of the cubic system with bright metallic lustre. As a rock-forming mineral it is widely distributed in schistose, slaty, and other rocks. The hardness is 6 to 6·5 in the scale, the sp. gr. varies from 4·9 to 5·2, and the streak is blackish. There is no cleavage and it breaks with an irregular fracture.

VIII. Olivine—so named from the *olive-green colour*—is a ferro-magnesian silicate. The crystals belong to the orthorhombic system, but well-developed crystals are somewhat rare. As a rule it occurs in compact or granular masses, or in small grains embedded in basic igneous rocks of which it is a component part. The cleavage is imperfect and it has a partially conchoidal fracture. The hardness is from 6·5 to 7 in the scale, and the sp. gr. is 3·3 to 3·4. The colour varies with the amount of iron it contains, and it possesses a vitreous or glassy lustre. Olivine is decomposed by hydrochloric acid. It is not a very stable compound and frequently alters to serpentine. Meteoric stones are largely composed of olivine and enstatite. The olivine specimen in the case is granular in type.

IX. Apatite—from the Greek *apate*, deceit, because it was often mistaken for other minerals.

We have here a mineral with a complicated composition, but it is essentially a phosphate of lime, containing small quantities of fluorine and chlorine, so that we have a fluor-apatite and a chlor-apatite. The crystals are frequently well developed and occur as hexagonal prisms which may be either tabular or prismatic in form. They vary from clear and transparent to a greenish or brownish shade of colour. There is no cleavage and when the crystals are broken the fracture is somewhat conchoidal. The hardness is 5 in the scale, and the sp. gr. is 3·2.

Apatite is also found plentifully in the form of compact and earthy masses when it is known as phosphorite. As a rock-former apatite is widely distributed in minute acicular crystals in all igneous and crystalline rocks. Occasionally in the veins and cavities of some of these rocks the crystals are finely developed.

X. Garnet—probably from the Latin [*pomum*] *granatum*, pomegranate, from its resemblance to the seeds.

This group consists of a number of isomorphous minerals crystallising in forms of the cubic system and having the same type of complex chemical formulæ. They are silicates of aluminium, calcium, magnesium, iron, and manganese, and according to the dominance of the chief constituent they vary in colour and in name. Thus the iron aluminium garnet is claret coloured and is known as almandine; the magnesian aluminium garnet is red and is known as pyrope—from the Greek *pyropus*, fiery—and so on. The crystals are generally developed as rhombic dodecahedra (12 rhombic faces), or as trapezohedra (24 trapezoidal faces). The cleavage is imperfect and the fracture is irregular. The hardness varies according to the composition from 6·5 to 7·5 in the scale, and for the same reason the sp. gr. has a wide range from 3·2 to 4·3. The colour is typically red though this changes much with the ingredients of the garnet. As rock-forming minerals they are widely distributed, occurring in crystalline schists, granites, and other rocks. The garnets are insoluble in acids.

XI. Topaz—from the Greek *Topazios*—in allusion to its occurrence in an island of that name in the Red Sea. Probably this was the mineral which is now known as chrysolite or transparent olivine.

Topaz is a fluo-silicate of aluminium having the chemical formula $Al_2F_2SiO_4$. It may be colourless, but frequently there is a colour range from pale green to brown. Some of the colours are unstable and liable to change on heating, as in the case of the pale brown Brazilian topaz. This mineral crystallises in the orthorhombic system and usually in prism form with pyramidal and basal terminations. There is perfect cleavage parallel to the basal plane. The sp. gr. is 3·5, and the hardness is 8 in the scale. It is not an important rock-former, but it is often met with in tin-ore veins and in the cavities of granite and pegmatite.

XII. Zircon—probably derived from the Arabic *zarkun*; allied to *Jargoon*, the name given to certain varieties of zircons.

In zircon we have a silicate of the metallic element zirconium with the chemical formula $ZrSiO_4$. It crystallises in the tetragonal system, and generally in prisms terminated at both ends by pyramids. There is no cleavage and the fracture is conchoidal. The sp. gr. varies from 4·6 to 4·7, and the hardness is about 7·5. In colour it is generally brown or red, but this varies somewhat; the ordinary zircon is opaque and the gem variety is transparent. Zircon is an accessory constituent of several rocks, as granite, syenite, and some of the eruptive basic formations. It is not easily weathered, so that it is frequently found in secondary sandy deposits, usually occurring as crystals with rounded edges.

XIII. Tourmaline—from *Tourmali*, the Cingalese name for tourmaline.

Tourmaline is a complicated compound, a boro-silicate of aluminium and iron with magnesium and alkalies, which crystallises in the rhombohedral system. The hardness is 7 to 7·5 in the scale, and the sp. gr. is from 2·94 to 3·24. As a rock-forming mineral the only form of any importance is the black variety known as schorl—from the German *Schörl*. Schorl generally occurs in trigonal (three-sided) prisms, so that a transverse section of the prism becomes triangular. The faces of the prism are striated longitudinally, and the colour is very dark green or black. The cleavage is indistinct and the fracture is uneven. In rock formations it is met with as microscopic prisms and grains, or as groups of radiating acicular crystals, while in other conditions it occurs in massive aggregates. As a rock-constituent it is a common ingredient of schistose rocks, and it is also found as a contact mineral in altered rocks surrounding igneous intrusions.

XIV. Sphene—from the Greek *sphen*, a wedge—alluding to the thin wedge-shaped crystals.

This mineral is a titano-silicate of calcium and has the chemical formula $CaTiSiO_5$. Sphene crystallises in the monoclinic system, and though the crystals vary much in habit they are generally thin and wedge-shaped. Sphene is also known as titanite. The colour is generally green, brown, or black, with a bright resinous lustre. The hardness is 5·5 in the scale, and the sp. gr. is 3·5. Large and perfect crystals are not very common, but they are sometimes found in the drusy cavities of igneous rocks. Usually as rock-formers the crystals appear as accessory constituents of microscopic size in eruptive rocks.

CHAPTER II

Igneous and Sedimentary Rocks. Cases A and B

Having described the principal rock-forming minerals, the rocks which are composed of aggregates of those minerals can now be examined.

In geology the term rock is used in a wide sense and includes an aggregate of minerals, whether hard and consolidated, or soft and incoherent. As a rule the soft incoherent rocks occupy surface positions, concealing to a large extent the hard, consolidated rocks which form such a huge portion of the crust of the earth.

The rocks are described according to the classification and arrangement of specimens exhibited in Cases A and B. They are divided into two great classes, viz. :—

A. Igneous Rocks—from the Latin *igneus*, fiery—in reference to their plutonic or fiery origin.

B. Sedimentary Rocks—from the Latin *sedimentum*, in reference to their deposition as sediments (*see* p. 38).

A. IGNEOUS ROCKS

Igneous rocks vary much in structure. This difference is largely governed by the surrounding conditions or environment of the molten mass from which rocks crystallise or consolidate. This molten mass is generally referred to as *magma*—a Greek word meaning mass or mixture. When this molten magma is pressed or squeezed into the crust of the earth and consolidates there at considerable depths from the surface, it has quite a different appearance and structure from magma which is forced through the crust of the earth and consolidates on the surface, as in the case of lava from a volcano. Hence, igneous rocks may be conveniently grouped into those masses which consolidate at considerable depths in the earth, and those masses which consolidate on the surface.

The former group of rocks is termed plutonic—from *Pluto* of the nether regions—or abyssal, and the latter group of rocks is named volcanic.

In the case of deep-seated, plutonic, or abyssal rocks the magma was under great pressure and at great depths from the surface, so that it cooled and consolidated slowly. The minerals which were in solution in the magma had time to crystallise, grow, and produce a solid mass or rock, composed entirely of crystalline constituents of various kinds and sizes. As a rule, in plutonic rocks the crystals are large and coarse, and this texture is described as coarse-grained crystalline texture. On the other hand, the magma or lava which was poured out from the volcano was relieved of pressure and was spread over a large surface where it cooled quickly. In some of this magma crystallisation took place, but it was too quickly consolidated for the crystals to attain much size. In other portions of the magma consolidation was too rapid for crystals to form or grow, there was no time or opportunity for the molecules to group themselves into definite crystalline form ; the magma remained a glassy, vitreous-looking material without crystalline structure. In those rocks where the crystals are very small a fine-grained or compact texture is produced ; and where there is no crystalline formation a glassy product is the result.

Frequently from deep plutonic masses some of the liquid magma was forced upwards through fissures in the crustal rocks in the form of dykes, or as sheets between the bedding planes of rocks in the form of sills which found no external outlet. These formations—dykes and sills—are intermediate between the plutonic or abyssal rocks and the volcanic group. They are termed hypabyssal rocks, meaning rocks that are formed above or nearer the surface than abyssal rocks. They cool more quickly than the plutonic and more slowly than the volcanic series, so that their texture differs in degree from both. Generally they are not so coarse-grained as plutonic, nor as glassy or fine-grained as volcanic rocks, though they may combine features of both. There is no hard and fast line for distinguishing these three groups from one another, the difference is one of degree, and they merge one into the other.

Plutonic and hypabyssal rocks are termed intrusive, and volcanic rocks are termed extrusive rocks, from their relative positions in regard to the crustal covering. Before intrusive rocks could be exposed, the superficial rocks of the crust must have weathered or decomposed, and denudation must have taken place ; or some great crustal movements must have upraised them to the surface ; or probably both agencies combined to produce the change.

For descriptive purposes igneous rocks are grouped under the three types stated above, viz. :—

(a) *Plutonic or Abyssal*—generally coarse-grained texture.
(b) *Hypabyssal*—medium- to fine-grained texture.
(c) *Volcanic*—fine-grained to glassy texture.

In Cases A and B the igneous rock series is divided into two groups, viz. :—

I. Crystalline Igneous Rocks—rocks composed more or less entirely of crystalline constituents.

II. Fragmental Igneous Rocks—composed of fragments of material ejected from volcanoes during eruption.

I. Crystalline Igneous Rocks

These rocks are again grouped into families, and specific names of the families are determined by the presence of certain minerals among the ingredients which compose the rocks. Generally speaking, well-developed, typical crystals of minerals are not often met with as constituents of igneous rocks, since pressure and mutual interference with one another prevented them from assuming their natural forms.

There are four families of rocks grouped according to the dominant felspars they contain, and one family in which there are no felspar constituents.

To the orthoclase felspars belong the granite and syenite families ; and the plagioclase series includes the diorite and gabbro families. The ultra-basic group has no felspar constituent.

The following is a tabulated form :—

Igneous Rocks	Orthoclase dominant	Orthoclase with quartz	Granites	Acid rocks.
		Orthoclase with little or no quartz	Syenites	Intermediate rocks.
	Plagioclase dominant	Plagioclase with soda in excess	Diorites	
		Plagioclase with lime in excess	Gabbros	Basic rocks.
	Ultra-basic rocks without felspars.			

I. Granite Family.—Granite—from the Italian *granito*, grained —in reference to the granular appearance.

Felspars alone cannot determine the family or species of a rock. Other minerals are necessary to mark the family character, and those minerals which mark the specific or family character are termed *essential minerals*. For example, if a rock contains dominant orthoclase and also a quantity of quartz and mica—either muscovite or biotite, or both—then that rock is called a granite, so that the essential minerals of a granite are orthoclase, quartz, and mica.

A rock may contain other minerals besides the essential minerals—it matters not how many—and those other minerals are termed *accessory minerals*. They do not affect the general character of the rock, but they add the qualifying name to the variety of rock. Take for example a granite with a predominating amount of hornblende among the accessory ingredients, then that granite would be termed a hornblende-granite. Again, if tourmaline is a predominant accessory mineral the granite would be termed a tourmaline-granite, and so forth.

In addition to the leucocratic essential minerals of granite, traces of albite or oligoclase may sometimes be found in the rock.

The following tabulated form represents the essential and accessory constituents of the granite family :—

Granite Constituents

Leucocratic.	Melanocratic.
Essential—Orthoclase, Quartz.	Muscovite, Biotite.
Accessory—Albite, Oligoclase.	Hornblende, Tourmaline, etc.

Orthoclase is the principal colouring mineral of granite, but the shade of colour varies with the relative proportion of ingredients.

a) *Abyssal Type.*

In this type the crystals vary much in size. In some specimens they form large pieces and give the rock a lumpy appearance as in pegmatite ; in others the crystals are smaller and more regular in size, and produce a granular structure known as 'coarse-grained' or 'granitoid texture.' The following specimens illustrate both varieties.

CASE A.

(1) **Pegmatite.** Locality, Rubislaw, Aberdeen.

Orthoclase + Quartz + Muscovite.

The crystals in this specimen are very large and form a lumpy looking rock. The orthoclase is pinkish brown, the quartz is pale grey, and the muscovite is in large silvery flakes. This is a large-grained granite or pegmatite, which is commonly found in veins associated with large intrusive masses of granite magma.

(2) **Tourmaline-Granite.** Locality, Aberdeenshire.

Orthoclase + Quartz + Muscovite + Tourmaline.

This specimen too is of the large-grained pegmatite type. The orthoclase is pinkish brown, the quartz is palish grey, and the muscovite scales are pale and shining. The large black crystals are tourmaline—hence a tourmaline granite.

(3) **Greisen.** Locality, Aberdeenshire.

Quartz + Muscovite + Tourmaline.

This rock is composed almost entirely of quartz and muscovite with a few black pieces of tourmaline as an accessory mineral. The quartz is the usual greyish colour, and the muscovite is in large silvery scales. This is another of these vein rocks associated with large intrusive masses. A rock composed almost entirely of quartz and muscovite is known by the term ‘greisen,’ a modified granite of the pegmatite type. Greisen—from the German *greisen*, to cleave or split.

(4) **Porphyritic Granite.** Locality, Rubislaw, Aberdeen.

Orthoclase + Quartz + Biotite + Pyrites.

The orthoclase is pinkish brown and grey, the quartz is glassy looking, the biotite is black, shining, and foliated, and the pyrites is in small yellowish-coloured grains with bright lustre. These minerals form a ground mass or matrix. They are more or less regular in size and give the rock a granular appearance. Throughout the coarse granular matrix are distributed large crystals of pinkish-brown orthoclase called phenocrysts. Phenocryst, from the Greek *phainein*, to show, +*kryst* (*allos*), a crystal, is a crystal that shows or is prominent. When large crystals are embedded in a ground mass of smaller crystals the rock is termed a porphyry—hence a granite porphyry. Porphyry is from the Greek *porphyreos*, purple—a name formerly applied to a reddish volcanic rock.

(5) **Graphic Granite.** Locality, Nairn.

Orthoclase + Quartz + Biotite.

Orthoclase is pinkish brown, quartz is palish-grey, and biotite is black and foliated. In some places the orthoclase and quartz show linear intergrowths, forming what is called 'graphic structure' from its resemblance to writing.

The remaining specimens of abyssal type are described as granitoid in structure—that is, their constituents are nearly equal in size and coarse in texture, giving the rock a granular appearance.

(6) **Binary Granite.** Locality, Aberdeenshire.

Orthoclase + Quartz + Muscovite + Biotite.

This rock has a somewhat pinkish-grey mottled appearance. The orthoclase is both pink and white in variety, and there is both muscovite and biotite (hence binary) among the constituents.

(7) **Biotite-Granite.** Locality, Ross of Mull.

Orthoclase + Quartz + Biotite + Microcline-Perthite.

Greyish pinkish brown in colour, coarse grained and granitoid in texture, this rock contains felspar and quartz in nearly equal proportions with some biotite and microcline-perthite.

(8) **Biotite-Granite.** Locality, Bonar Bridge, Sutherland.

Orthoclase + Quartz + Biotite.

This specimen is mottled pale grey with a tinge of pink. The felspar is a dull greyish-white colour and is in excess of the vitreous-looking quartz. The black foliated crystals of biotite are plentiful.

(9) **Hornblende-Granite.** Locality, Galloway.

Orthoclase + Quartz + Biotite + Hornblende.

A black and white spotted rock. The dull white felspar is slightly in excess of quartz and biotite, and hornblende crystals are the dominant ferro-magnesian mineral.

(10) **Biotite-Granite.** Locality, Dalbeattie.

Orthoclase + Quartz + Biotite.

This is a whitish-grey rock with a pale pink tinge and dark spots. The felspar, quartz, and biotite are so distributed as to give the specimen a black and white spotted appearance.

(11) **Binary Granite.** Locality, Aberdeenshire.

Orthoclase + Quartz + Muscovite + Biotite.

This granite is grey in colour with a pale pink tinge and dark spots. The orthoclase is very pale pinkish-white, the glassy-

looking quartz is in excess of the felspar, and crystals of muscovite and biotite are plentiful. The blending of the colours gives a greyish mottled appearance.

(12) **Riebeckite-Microgranite.** Locality, Ailsa Craig.
Anorthoclase + Quartz + Riebeckite.

A pale pinkish-grey rock with fine crystalline texture composed essentially of soda orthoclase, quartz, and riebeckite. The larger dark-blue crystals in the finer crystalline matrix are riebeckite—a soda amphibole. Riebeckite is named after *Dr Riebeck.*

(b) *Hypabyssal Type.*

As a rule the ground mass or matrix in this type of rock consists of microcrystalline aggregates of quartz and orthoclase. Very often phenocrysts of quartz and orthoclase, and sometimes mica or hornblende, are found embedded in the matrix producing the kind of rock already referred to as porphyry. Both in the hypabyssal and the volcanic types of rock where the structure is finely granular or compact, it is necessary to have a microscopic examination of the rock before the identification of the constituent parts can be determined.

The hypabyssal group is a somewhat artificial one as it merges on the one hand into the coarse-grained abyssal type, and on the other hand into the fine-grained and vitreous types of the volcanic group. If the ground-mass contains both crystalline and glassy material the rock is described as 'hemicrystalline'—part crystalline and part glassy.

(13) **Hornblende-Porphyry.** Locality, Lanarkshire.
Orthoclase + Quartz + Biotite + Hornblende.

A rock reddish brown in colour with a matrix of medium-grained texture, composed chiefly of reddish-brown orthoclase, quartz, biotite, and hornblende. Throughout the matrix phenocrysts of hornblende are embedded.

(14) **Quartz-Porphyry.** Locality, Galloway.
Orthoclase + Quartz + Biotite.

This is a rock of medium to fine crystalline texture, and throughout the matrix are embedded larger crystals of dull, cream-coloured felspars, quartz, and biotite.

(15) **Felsite.** Locality, Tinto.

This specimen is a brick-red rock with fine crystalline matrix in which are embedded numerous phenocrysts of dull, greyish,

decomposing felspars and a few dark-green grains of biotite. This type of rock is termed felsite. Felsite is derived from German *fels*, rock, +*ite*. Felsitic matter is composed of very fine-grained aggregates of quartz and felspar, and felsite is the rock composed chiefly of this matter.

(c) *Volcanic Type.*

This type includes all true acid lavas, the extrusive products of volcanic action. The ground-mass usually contains some glassy or devitrified residue, and porphyritic crystals are frequently found disseminated through it.

Rhyolite is the term applied to volcanic rocks when the fine crystalline matrix is in excess of any vitreous or glassy residue. Rhyolite is derived from the Greek *rhein*, to flow—on account of flow structure being frequently met with in this kind of rock.

Pitchstone is the name given to the rock when a vitreous matrix is dominant; the matrix frequently contains incipient forms of crystallisation called 'microlites' (microscopic grains). Pitchstone—so called from its *pitch-like* appearance.

Obsidian is a term applied to a rock when the matrix is composed entirely of glassy material without crystalline formation. Obsidian is derived from *Obsius* or *Obsidius*, who described similar rocks which he discovered in Ethiopia.

(16) **Rhyolite.** Locality not known.

This is another rock of felsitic type. It is pinkish brown in colour with a very fine compact matrix, and there is flow structure in the form of bands which vary slightly in colour and fineness of texture. The specimen is divided by a vein in which crystals of quartz, felspar, and shining plates of muscovite can be readily recognised.

(17) **Pitchstone.** Locality, Ascension Island.

This representative of the vitreous state of acid volcanic rocks is dark green-black in colour with a pitch-like resinous lustre. The fracture is somewhat conchoidal, and flow structure is also apparent in this specimen.

(18) **Obsidian.** Locality, Arran.

There are two specimens here to represent the glassy or vitreous formation of acid lava without crystallisation. One specimen is bluish-grey and shows well-marked flow structure. The other is dark green-black. Both specimens possess a splintery conchoidal fracture.

(19) **Pumice-stone.** Locality, New Zealand.

The last exhibit in the granite series is a glassy lava full of small vesicles or vapour cells which give it a frothy or spongy appearance. It generally develops as a crust on some acid lavas, or as slabby pieces, or as cinders. This species of rock is called pumice-stone. Pumice—derived from the Latin *pumex*, froth.

All the rocks of the granite family are rich in silica, and, being rich in silica, they are often termed acid rocks. They have all developed from a molten magma of a fairly even chemical composition, and their different petrological aspects are due mainly to the varied conditions under which they cooled and consolidated.

II. Syenite Family.—Syenite—from the place-name *Syene* in Egypt.

The members of this family in some respects are not unlike the members of the granite family. The dominant felspars are similar, many of the rocks are granitoid in texture, and frequently there is a resemblance in colour. In syenite the essential minerals are orthoclase and hornblende. The usual accessory minerals on the leucocratic side are oligoclase and quartz, and on the melanocratic side biotite and augite. In tabulated form the essential and accessory minerals are as follows :—

Syenite Constituents

	Leucocratic.	Melanocratic.
Essential—	Orthoclase.	Hornblende.
Accessory—	Oligoclase, Quartz.	Biotite, Augite.

As in granite the dark-coloured accessory constituents give the qualifying name to the variety of rock. When biotite is present in quantity the rock is termed a biotite-syenite, or if augite is a plentiful constituent it is termed an augite-syenite, and so on. Sometimes, however, the leucocratic accessory mineral provides the qualifying name, as when quartz is well represented the rock is termed a quartz-syenite.

(a) *Abyssal Type.*

In this type the rocks are coarse-grained, granitoid, and holocrystalline—*i.e.* entirely crystalline—in texture.

(1) **Syenite.** Locality, Ben More District, Assynt.
Orthoclase + Pyroxene + Quartz.

This specimen is a spotted reddish-brown and dark-green rock. The orthoclase is the large reddish-brown crystals, and the pyroxene crystals are large and very dark-green. There are a few grains of vitreous-looking quartz.

(2) **Syenite (Perthosite).** Locality, Ben More District, Assynt.
Dominantly alkali-felspars.

This rock has a pinkish-grey colour, and its crystalline texture is coarse granitoid. There are both pink and grey crystals of felspar; dark-green pyroxene and secondary muscovite in small silvery scales are present to a small extent.

(3) **Melanite-Syenite.** Locality, Loch Borolan, Assynt.
Felspar + Hornblende + Garnet.

A greyish mottled-looking rock of coarse granitoid texture. The orthoclase is grey, the hornblende is dark-green, and the garnet is black. The black garnet is lime-iron garnet, named from its black colour melanite — hence a melanite-syenite. Melanite—from the Greek *melan*, black, + *ite*.

(4) **Quartz-Syenite.** Locality, Syene, Egypt.
Felspar + Hornblende + Biotite + Quartz.

In appearance this specimen resembles granite and the texture is granitoid. Orthoclase crystals are pink, hornblende is dark green-black, biotite is shiny black, and quartz is grey and vitreous looking—a quartz-syenite.

(5) **Quartz-Syenite.** Locality, Loch Borolan.
Orthoclase + Hornblende + Quartz.

This is another rock which resembles granite in appearance. It is pinkish-brown in colour and has a coarse granitoid texture. Orthoclase is pink, hornblende is dark-green, and quartz is grey and glassy—a quartz-syenite.

The quartz-syenites are connecting links between the granites and syenites.

(6) **Riebeckite-Syenite.** Locality, Ben More District.
Felspar + Pyroxene + Riebeckite.

A pinkish-grey, granitoid, crystalline rock. The felspar is both pink and grey in variety, pyroxene is dark-green, and riebeckite is dark-blue—a riebeckite-syenite.

(b) *Hypabyssal Type.*

In this type there is a fine crystalline matrix which consists essentially of microcrystalline orthoclase, and sometimes includes small scales of biotite and needles of hornblende. Embedded in the matrix there are generally phenocrysts of orthoclase or hornblende or other ferro-magnesian constituents. This type of porphyry is generally termed orthoclase-porphyry.

(7) **Rhomb-Porphyry.** Locality, South Norway.

This rock consists of a fine-grained, very dark grey ground-mass throughout which are embedded large rhomb-shaped crystals of dark grey soda orthoclase or anorthoclase—hence rhomb-porphyry.

(8) **Phonolite.** Locality, Fintry.

A reddish-brown, fine-grained, crystalline rock with dark-green mottling. It is composed mainly of orthoclase, with many ragged crystals of dark-green hornblende; nepheline is also present.

Phonolite—from the Greek *phone*, sound, +*lithos*, a stone —a name given to it by Klaproth on account of the ringing noise it makes under the hammer.

(c) *Volcanic Type.*

Volcanic syenite rocks are termed trachytes. Trachyte—from the Greek *trachys*, rough—describes the rough feeling which many of those rocks possess, and which is due to numerous small air vesicles on the broken surface. The matrix may be either compact or somewhat porous, and is composed essentially of microscopic lath-like crystals of sanidine. Some glassy residue is generally present in the trachyte matrix. Throughout the ground-mass phenocrysts of sanidine are frequently met with, and crystals of hornblende or biotite are not uncommon.

(9) **Trachyte.** Locality, Eildon.

This is a pinkish to brownish-grey fine-grained rock. Embedded in the matrix are phenocrysts of sanidine which are much decomposed.

(10) **Trachyte.** Locality, Eildon.

This specimen of trachyte is a reddish-brown compact-looking rock. Many dull, cream-coloured, decomposing felspars are scattered through the ground-mass.

III. Diorite Family.—Diorite—from the Greek *diorizein*, to distinguish—a term used by Haüy for rocks composed chiefly of plagioclase and hornblende to distinguish them from granites.

In this family the plagioclase felspars are the dominant felspar constituents. The typical diorite is a rock which consists of plagioclase—ranging from oligoclase to labradorite—as the leucocratic mineral, and hornblende as the dominant melanocratic constituent.

As accessory minerals, orthoclase and quartz may be present in subordinate amount, and when they are present the composition of the rock is intermediate between granite and diorite. A rock of this nature is termed a quartz-diorite or tonalite. Tonalite—from *Tonale*, in the Western Alps, whence specimens of those rocks were obtained.

When biotite is present in subordinate quantity the rock is termed a mica-diorite, and similarly if augite is present the term augite-diorite is applied to it.

The following is the tabulated formula of diorite :—

Diorite Constituents

	Leucocratic.	Melanocratic.
Essential—	Oligoclase, Labradorite.	Hornblende.
Accessory—	Orthoclase, Quartz.	Biotite, Augite.

(a) *Abyssal Type.*

In this type the texture is granitoid and holocrystalline. As a rule the crystals are less coarse and more regular in size than in granites.

Case B

(1) **Diorite.** Locality, Aberdeenshire.

Plagioclase + Hornblende + Biotite.

This is a coarse-grained granitoid rock and in appearance it is speckled black and white. The felspar oligoclase is white, and the hornblende very dark-green. There are black shining scales of biotite.

(2) **Diorite.** Locality, Taynuilt.

Plagioclase + Hornblende + Biotite.

This rock has a mottled grey appearance and in texture it is granitoid and holocrystalline. The plagioclase is grey, the hornblende is dark-green, and the biotite is black and foliated.

(3) **Diorite.** Locality, Glenarm, Galloway.

A dark brownish-green rock, heavy and compact, medium in texture and composed essentially of plagioclase, hornblende, and biotite.

(4) **Quartz-Diorite, or Tonalite.** Locality, Kirnielaw.

Plagioclase + Orthoclase + Quartz + Hornblende + Biotite + Pyrites.

This specimen is a pale greyish-coloured, coarse-grained, crystalline rock with weathered edges. The felspars are dull white in colour, quartz is glassy-looking, hornblende is dark-green, biotite is black, and pyrites is in small yellowish-coloured grains.

(b) *Hypabyssal Type.*

The diorite hypabyssal type of rock is termed porphyrite. The soda-lime felspar is dominant, and there is usually a porphyritic structure. The matrix or ground-mass is fine-grained, and throughout it phenocrysts of felspar, hornblende, or biotite are frequently embedded.

(5) **Porphyrite.** Locality, Galloway.

This rock presents a fine-grained crystalline matrix, grey in colour, and embedded in it are phenocrysts of hornblende and felspar.

(c) *Volcanic Type.*

The andesites represent the volcanic type of the diorites. Andesite—so named from the *Andes Mountains*, whence specimens were obtained.

The ground-mass, generally fine-grained, compact, or vesicular, consists essentially of lath-like microlith crystals of plagioclase, which usually show flow structure. It also frequently contains minute granules of hornblende, biotite, or hypersthene. The rocks are often porphyritic, and the phenocrysts are generally crystals of plagioclase and one or more of the ferro-magnesian constituents. The andesites which contain quartz are termed dacites. Dacite—from *Dacia*, formerly a Roman province, now Transylvania.

(6) **Dacite.** Locality, Lucklaw.

This specimen is brick-red in colour and has a solid compact-looking matrix in which are embedded phenocrysts of plagioclase and a few small green-looking crystals of hornblende. The fracture is uneven.

(7) **Dacite.** Locality, Wornut Bay.

This rock is pinkish-brown in colour and has a fine-grained compact matrix in which numerous dull, cream-coloured, decomposing phenocrysts of plagioclase are embedded.

(8) **Andesite.** Locality, Blackford Hill, Edinburgh.

This is a very dark-coloured rock with a faint purplish tinge. The matrix is uniform and compact, the fracture is uneven, and the rock has a slaty appearance.

(9) **Hypersthene-Andesite.** Locality, Ochil Hills.

The specimen is a greyish-black, basic-looking rock. The ground-mass is fine-grained and compact, and contains hypersthene and phenocrysts of plagioclase. There is a vein of jasper running through the rock.

(10) **Andesite.** Locality not known.

The lava is dark coloured and full of vapour vesicles which are filled with deposits of silica.

IV. Gabbro Family.—Gabbro is an Italian word meaning a kind of green-stone, applied originally to some coarse-grained greenish rocks in the North of Italy.

This family includes the more basic members of the soda-lime series of plagioclase. It is composed essentially of labradorite and anorthite as the leucocratic minerals, and diallage, augite, or hypersthene as the melanocratic ingredients.

The following is the tabulated formula of gabbro :—

Gabbro Constituents

	Leucocratic.	Melanocratic.
Essential—	Labradorite, Anorthite.	Diallage, Augite, Hypersthene.
Accessory—	Andesine, Oligoclase.	Biotite, Olivine, Hornblende.

Gabbros range in texture from coarse-grained or granitoid to fine-grained crystalline rocks. In colour they are somewhat

mottled or speckled. The felspars are bluish-grey, and the ferromagnesian minerals are green to black.

(a) *Abyssal Type.*

(1) **Gabbro.** Locality, Skye.

Plagioclase + Diallage.

This is a very coarse-grained holocrystalline rock, mottled grey and greyish-green. The large grey crystals are basic plagioclase, and the dark greyish-green crystals are diallage.

(2) **Gabbro.** Locality, Carrick Luz, Cornwall.

Plagioclase + Diallage.

This is another coarse-grained granitoid rock, greyish-green in colour. The essential constituents are labradorite and diallage.

(3) **Hypersthene-Gabbro or Norite.** Locality, Huntly, Aberdeenshire.

Plagioclase + Hypersthene + Augite.

This specimen is a medium-grained holocrystalline rock, dark-grey in colour. The grey material is chiefly labradorite, the dark-coloured crystals are principally hypersthene, the dominant ferromagnesian mineral. Augite is present in subordinate degree.

A rock composed of labradorite and hypersthene as the dominant constituents is termed norite. Norite is an abbreviation for *Norwayite*—Nor(way), + *ite*, a term applied to some gabbros in Norway.

(4) **Essexite.** Locality, Lanarkshire.

A heavy, dark-grey, compact rock. The matrix is fine-grained and consists chiefly of soda-lime felspars with augite, olivine, nepheline, and other minerals. In it are embedded numerous phenocrysts of augite. Essexite—from the place-name Essex County, Mass., U.S.A.

(b) *Hypabyssal Type.*

Dolerite is the principal hypabyssal rock of the gabbro family, and is chiefly met with in bosses, dykes, and sills. It is composed essentially of plagioclase, augite, and iron oxides. Other minerals contained in the rock produce varieties of this type.

(5) **Quartz-Dolerite.** Locality, Turnhouse, Midlothian.

A medium-grained holocrystalline rock, spotted greenish-black and whitish-grey. The greyish crystals are plagioclase, the dark crystals are augite, and some glassy-looking quartz crystals are distributed through the mass.

(6) **Quartz-Dolerite.** Locality, Kaimes, Midlothian.

A fine-grained, very dark, basic-looking rock composed chiefly of plagioclase, augite, iron oxides, and quartz.

(7) **Olivine-Dolerite.** Locality, Corstorphine Hill, Midlothian.

A fine-grained holocrystalline rock, grey in colour with a faint bluish tinge. The dominant constituents are plagioclase, augite, and olivine.

(8) **Hypersthene-Dolerite.** Locality, Craigrothie.

A dark, dull, heavy, basic-looking specimen with compact matrix. The principal minerals are plagioclase, augite, and hypersthene with iron oxides.

(9) **Analcite-Dolerite or Teschenite.** Locality, Salisbury Craigs, Edinburgh.

Dark grey in colour, medium- to fine-grained in texture, this rock is composed chiefly of plagioclase, augite, iron oxides, and analcite which is generally a secondary product.

Teschenite—so named from *Teschen*, a town in Silesia.

(10) **Mugearite.** Locality, Corston Hill, Midlothian.

This specimen is a dark-grey, fine-grained, compact-looking rock. It is composed chiefly of plagioclase, augite, olivine, iron oxides, and some alkali felspar.

Mugearite—named from *Mugeary*, a village in Skye.

(11) **Epidiorite.** Locality, Ross of Mull.

This is another dark-grey, crystalline, basic rock. It has a medium-grained texture and consists chiefly of plagioclase, augite, hornblende, and iron oxides. It has undergone a metamorphic change and some of the augite has been converted into hornblende.

(12) **Dolerite.** Locality, Ravelrig, Midlothian.

A heavy, compact, brownish-black rock showing changes from weathering.

(c) *Volcanic Type.*

Basalt lava represents the volcanic type of gabbro magma. Basalt—from the Ethiopian word *basal*, signifying a stone that yields iron. According to Pliny, the first basalts were obtained in Ethiopia. Lava—an Italian word applied to the liquid products of volcanic activity.

Basalt is a dark-coloured, dense, basic rock of high sp. gr. It varies in texture from porphyritic to minutely crystalline, and sometimes the matrix contains glassy residue. The heavy weight

and dark colour are due mainly to ferro-magnesian compounds. Essentially it is composed of basic plagioclase and augite.

Lava is any molten rock that flows from a volcano. In the gabbro magma the lava is basic, sometimes consisting of crystalline particles, sometimes of a stony, devitrified matrix with constituent crystals embedded in it, or it may be entirely vitreous. In texture it varies from solid to minutely vesicular.

(13) **Olivine-Basalt.** Locality, Arthur's Seat.

A dark, heavy, basic-looking rock which consists essentially of crystalline granules of plagioclase, augite, and olivine. In the granular matrix are larger crystals of plagioclase and augite.

(14) **Porphyritic Basalt.** Locality, Carnethy Hill, Midlothian.

Another dark, basic, heavy rock with a fine-grained matrix. Throughout the matrix there are numerous large phenocrysts of plagioclase—pale-green labradorite. There are also a few vesicles filled with silica.

(15) **Porphyritic Basalt.** Locality not known.

Similar to number 14 and polished.

(16) **Basalt.** Locality not known.

In this specimen there is a glassy material in the matrix termed basaltic glass or tachylite. Tachylite—from the Greek *tachys*, swift, +*luein*, to dissolve—meaning rapidly fused.

(17) **Ropy Lava.** Locality, Italy.

A rough dark mass of lava which shows a rope-like flow structure due to the pulling out or stretching of semi-fluid magma while in motion.

(18) **Vesicular Lava.** Locality, Staffa.

This specimen has a greyish appearance with a more or less solid matrix which contains numerous vesicles or vapour cavities.

(19) **Pumice.** Locality, New Zealand.

In this piece of dark-coloured lava there is an immense number of small vesicles or air cavities which give the specimen a spongy look and produce a low sp. gr.

(20) **Amygdaloidal Lava.** Locality, Staffa.

A lava with vesicular cavities varying in size, and many of which are filled with deposits of silica.

Amygdaloid—Greek *amygdale*, an almond, +*eidos*, form—from the almond shape which some of the vesicles frequently assume.

V. Ultra-basic Rocks.

Ultra-basic rocks have no felspar constituents. They are composed essentially of hornblende and pyroxenes. The accessory minerals are chiefly biotite, olivine, and iron oxides. They occur as plutonic masses or as dykes, and are heavy dark-coloured rocks.

(1) **Hornblendite.** Locality, Cape Wrath.

A dark-green, coarse-grained rock, composed chiefly of hornblende and pyroxenes—hornblende in excess.

(2) **Pyroxenite.** Locality, Loch Ailsh, Sutherland.

A coarse-grained, greenish-black, basic rock, composed principally of pyroxenes and hornblende—pyroxenes in excess.

(3) **Eclogite.** Locality, Sweden.

A dark-coloured basic rock, composed essentially of pyroxene and red garnets. The white material is calcite deposit. Eclogite —from the Greek *ekloge*, selection—a term used by Haüy for a rock composed of pyroxene and garnet.

(4) **Picrite.** Locality, Ayrshire.

Very dark-coloured, heavy, basic rock, the chief constituents of which are augite and olivine. Picrite—from the Greek *pikros*, bitter—a term used for a variety of olivine-rock.

Following the ultra-basic rocks there are two rock specimens, viz. :—

(1) **Lamprophyre**—from the Greek *lampros*, bright, +(*por*)*phyreos*, purple—a name first used by Gümbel.

Lamprophyres are composed chiefly of ferro-magnesian minerals with subordinate felspars, and occur as a rule in the form of dyke rocks. They have a wide range of chemical composition, and occur mostly as apophyses of large plutonic masses.

(2) **Aplite**—sometimes written **Haplite**—from the Greek *haplos*, simple, +*ite*—a name given to a crystalline mixture of quartz and orthoclase.

Large masses of granite are frequently traversed by veins or dykes of coarser or finer character. Coarse veins are termed pegmatite, and the fine-textured acid veins are termed aplite.

II. Fragmental Igneous or Pyroclastic Rocks

Pyroclastic—from the Greek *pyr*, fire, +*klastos*, broken—broken by volcanic or fiery agencies.

Fragmental igneous or pyroclastic rocks consist of material

that has been ejected from volcanoes during volcanic activity. The ejectamenta vary much in character from solid pieces of rock to fine dust or ash. If pyroclastic rocks contain large and small fragments embedded in a matrix of comminuted rock debris and grit they are known as agglomerates, and they are usually found in or near the vents of volcanoes. Again, if they are composed of smaller angular fragments the rocks are termed breccias, and if they consist chiefly of fine-grained ejectamenta they are classed as tuffs. Agglomerate—from the Latin *agglomeratus*, gathered into a ball or mass. Breccia—an Italian word meaning gravel. Tuff—from the Italian *tufo*, a soft stone.

(1) **Agglomerate.** Locality, John o' Groats.

A rough grey-looking rock composed of sub-angular fragments of various sizes embedded in a matrix of fine volcanic material. In the matrix are several large crystals of black augite.

(2) **Agglomerate.** Locality, King's Park, Edinburgh.

A heavy brown rock composed of small volcanic fragments surrounded by a fine-grained matrix.

(3) **Breccia.** Locality not known.

A brownish-grey rock with a fine-grained matrix embedding numerous soft, angular, greyish-coloured fragments.

(4) **Tuff.** Locality not known.

A yellowish-grey rock with a softish, fine-grained matrix in which are embedded numerous small roundish fragments of volcanic origin.

(5) **Tuff.** Locality, New Zealand.

A slightly porous brick-red rock. The texture is fine-grained and it can be readily scratched with the finger-nail.

(6) **Tuff.** Locality, Mont Pelée, West Indies.

A dark vesicular-looking rock composed chiefly of volcanic ashes.

(7) **Tuff.** Locality, Mont Pelée.

A pale-grey porous rock. It is fine-grained in texture and can be readily scratched with a knife.

(8) **Volcanic Dust.** Locality, Mont Pelée.

A bottle containing fine volcanic dust.

(9) **Volcanic Dust.** Locality, Tarawra, New Zealand.

A phial containing volcanic dust.

(10) **Volcanic Dust.** Locality, Vesuvius.

A glass tube containing several specimens of volcanic dust of varying fineness from Vesuvius.

B. SEDIMENTARY ROCKS

The next exhibit is a series of water-worn stones to show how rocks get broken up and detached as fragments in the natural process of weathering. These fragments undergo further disintegration, and many of them are conveyed by superficial agencies into rivers, lakes, and seas. In running or rolling water the friction of one rock against another removes the sharp edges of fragments and produces the smooth rounded surfaces characteristic of water-worn rocks. Weathering and friction reduce those rocks to pebbles, sand, silt, and mud. The pebbles represent the type of rock from whence they came, and the sand is made up chiefly of the more stable minerals which composed the rock. Such deposits represent the wastage of the solid land, and it is by their slow accumulation that sedimentary rocks are formed.

A rock composed of rounded water-worn stones, cemented together in a fine-grained matrix, is termed a conglomerate. When the constituent fragments which make up the rock are coarse and angular that rock is known as breccia. Rocks composed of finer sediments are termed grits and sandstones. The finest sediment or mud produces the rock called mudstone. The difference in texture between these various groups is one of degree ; they graduate towards each other.

(1) **Conglomerate.** Locality not known.

A brownish-grey rock composed of rounded pebbles of various sizes and kinds embedded in a calcareous matrix. Calcareous—from the Latin *calx*, lime—a limy matrix.

(2) **Conglomerate.** Locality, Leadburn.

A dark-coloured, hard, heavy rock with fine-grained siliceous matrix surrounding rounded pebbles of various kinds and sizes.

(3) **Conglomerate.** Locality, Peebles.

A dark-grey rock with fine-grained siliceous matrix in which are embedded numerous slaty-looking fragments and quartz crystals—greywacke type.

(4) **Breccia.** Locality, Screel Glen, Galloway.

A brownish-grey, heavy rock with angular fragments of

various kinds cemented together by a siliceous matrix. Siliceous—from silica.

The usual constituents of sand are those rock-forming minerals which are least prone to chemical change such as quartz, mica, felspar, magnetite, etc. The grains of sand are cemented together by an interstitial deposit, which may be siliceous, calcareous, ferruginous, or argillaceous (muddy), to form the rock which is termed sandstone. The hardness and the colouring of this rock depend largely on the cementing material. Quartz is the chief constituent of sand, and other minerals make up a small percentage only.

(5) **Grit.** Locality, Loch Torridon.

This specimen is greenish-grey in colour with some brown speckling, and consists of fine and coarse grains of sand and small pebbles. They are cemented together by a siliceous material and form a quartzite rock.

(6) **Grit.** Locality, Loch Torridon.

A hard, brownish-coloured rock, composed of coarse sand grains cemented together by a siliceous deposit forming a quartzite rock.

(7) **Grit.** Locality not known.

A rock grey in colour, hard in consistency, with grains regular in size and cemented together by a fine-grained interstitial deposit of an argillaceous nature.

(8) **Sandstone.** Locality, Isle of Wight.

A greenish-coloured rock composed of fine sand grains and chalky deposit, cemented together by argillaceous material. It is softish in consistency and in it are embedded a few beautiful shell fossils.

(9) **Sandstone.** Locality, High Burn Quarry, Durham.

Pale-grey in colour, hard in consistency, medium to fine in texture, with a siliceous interstitial deposit.

(10) **Sandstone.** From the pedestal of the Old Town Cross, Peebles.

Pale-grey to brown in colour, with medium-grained matrix. The cementing material is a thin siliceous deposit of medium consistency.

(11) **Torridon Sandstone.** Locality, Loch Torridon.

A purplish-brown, hard, compact-looking rock, with a ferruginous cementing material.

(12) **Micaceous Sandstone.** Locality not known.

Pale-brown in colour, medium in hardness, and medium to fine in texture, with numerous small flakes of muscovite throughout the matrix.

(13) **Sandstone.** Locality, North Berwick.

Brick-red, fine-grained, heavy rock of medium consistency, with ferruginous cementing deposit. In the fine matrix there are numerous pale yellow-green concretions of decomposing phosphate of iron.

(14) **Sandstone.** Locality not known.

A yellowish-grey, fine-grained, heavy rock, with fossil markings (Lepidodendron). The cementing material is a ferruginous-argillaceous deposit.

(15) **Greywacke Sandstone.** Locality, Peebles.

Dark-grey, hard, fine-grained rock, with interstitial calcareous deposit. Some slaty fragments are embedded in the matrix.

(16) **Quartzite.** Locality, Killiecrankie.

Pale-grey, hard rock composed chiefly of quartz grains embedded in a quartz matrix. This is a sandstone which has undergone a metamorphic change.

(17) **Mudstone.** Locality not known.

Very fine matrix of medium consistency, throughout which there are blue-coloured concretions of phosphate of iron.

(18) **Mudstone.** Locality, Lamancha.

An iron-stained rock of fine texture.

(19) **Mudstone.** Locality not known.

A brittle, rough-looking, but fine-grained mass of sun-dried mud.

(20) **Mudstone.** Locality not known.

A fine-grained, iron-stained rock.

(21) **Flexible Sandstone.** Locality, New Zealand.

A greyish rock specimen with a pinkish tinge, composed chiefly of medium-grained sand. This elongated piece of sandstone is flexible. In this form of sandstone the quartz granules are separated by fine scales of mica, talc, and chlorite. Sometimes the scales are so arranged as to allow a certain amount of flexibility to the stone—hence termed ‘ flexible sandstone.’

CHAPTER III

A. Organically Formed Rocks. B. Chemically Formed Rocks. C. Metamorphic Rocks. Case C

A. ORGANICALLY FORMED ROCKS.

We now pass from rocks formed of inorganic material to rocks derived from organic remains.

Rocks derived from organic remains are conveniently divided into two groups, viz. :—

I. Rocks derived from Animal Remains.
II. Rocks derived from Plant Remains.

We have already referred to the crust of the earth as composed of rocks, namely, aggregates of mineral matter of various kinds. We have also seen that the chemical composition of a rock is not definite, but that it varies according to the relative proportion of its mineral constituents. Under the general term rock are included materials varying in cohesion from debris to compact stone.

In chemical composition the older rocks of the earth's crust contain something like 3·50 per cent. of the element calcium, which never occurs in a free state but is generally in combination with oxygen and united with acids. In this form it produces numerous compounds and becomes an important rock-constituent both in igneous and sedimentary formations. In combination with silica (SiO_2) it forms silicates, and combined with carbon dioxide or carbonic acid (CO_2) it produces calcite or carbonate of lime and other rocks of the limestone group. This calcite or carbonate of lime is soluble in meteoric water containing carbonic acid, and in solution is carried by rivers to lakes and seas where it supplies the material for foraminifera, corals, molluscs, and other invertebrate species to form their tests and skeletons. These in their turn produce great accumulations of organic remains from which masses of limestone are formed. Sometimes the older limestone rocks, which were composed essentially of calcareous

shells, the hard parts of molluscs, echinoderms, and other organisms, have undergone so much change that all trace of organic structure is lost, while the rock at the same time assumes a crystalline texture. Many varieties of limestone are named from the organic structures most apparent in them.

I. Rocks derived from Animal Remains

(a) *Calcareous Remains*

(1) **Crystalline Limestone.** Locality not known.

A solid, heavy rock, brownish-grey in colour, fine in texture, containing very few organic remains. It is readily scratched with a knife and it effervesces when treated with hydrochloric acid.

(2) **Chalk.** Locality not known.

A white or greyish-white rock, fine-grained and soft in consistency. When touched it leaves a powdery mark on the fingers, and it dissolves with effervescence when treated with hydrochloric acid. It is largely composed of the remains of the hard and shelly parts of foraminifera together with fine debris of other calcareous organic remains. Foraminifera -from the Latin *foramina*, pores — from the pores or openings in the tests or coverings.

(3) **Crinoidal or Encrinital Limestone.** Locality not known.

A heavy, dark-grey specimen, fine in texture, easily scratched with a knife, which effervesces on the application of hydrochloric acid. It contains abundant remains of crinoids or encrinites—hence the variety.

Crinoidal—from the Greek *krinon*, a lily, +*eidos*, form—lilylike form or structure.

(4) **Crinoidal Limestone.** Locality not known.

This specimen is grey in colour with a faint tinge of green. One surface is polished and shows abundant organic remains of encrinites or crinoids.

(5) **Crystalline Limestone.** Locality not known.

This is another fine-grained limestone, embedding small fragments of shells. Like all other limestones it effervesces with hydrochloric acid and it is easily marked with a knife. On the upper surface there is the fossil marking of a cephalopod. Cephalopoda—a class of molluscs (*see* p. 186).

(6) **Shelly Limestone.** Locality not known.

A dark-grey rock with fine-grained matrix in which are embedded large quantities of brachiopod shells. Brachiopoda—a group of mollusc-like animals.

(7) **Shelly Limestone.** Locality not known.

A pale cream-coloured rock composed largely of gastropod shells embedded in a fine calcareous material. Gastropoda—a group of molluscs.

(8) **Coral Limestone.** Locality not known.

A dark-grey specimen composed essentially of coral embedded in a fine calcareous cement.

(9) **Oölitic Limestone.** Locality not known.

A pale cream-coloured rock, granular in appearance and composed of small fragments of shells and rounded grains of calcareous matter cemented together with a very fine calcareous sand or mud.

Oölitic—from the Greek *ōon*, an egg, +*lithos*, a stone—from its resemblance to fish roe or eggs.

(10) **Magnesian Limestone.** Locality not known.

A very fine-grained compact stone, pale-grey in colour, which breaks with a somewhat conchoidal fracture. The rock consists essentially of carbonates of calcium and magnesium, and is known as dolomite or magnesian limestone. Dolomite—named after the French geologist *Dolomieu*.

(11) **Arenaceous Limestone.** Locality not known.

A brownish-grey rock, banded in appearance and composed chiefly of calcite and sand—hence arenaceous limestone, sometimes called 'cornstone.'

Arenaceous—from the Latin *arena*, sand—sandy.

(12) **Argillaceous Limestone.** Locality, Slough, Bucks.

A very fine-grained, compact-looking rock, grey in colour and fracturing with an uneven surface. It consists principally of calcite and very fine sand or mud. This species of rock is also known as 'cement stone.'

Argillaceous—from the Latin *argilla*, clay—clayey.

(b) *Siliceous Remains*

Silicon as an element forms nearly 28 per cent. of the older crustal rocks, and always occurs united with oxygen (SiO_2), which when combined with water (H_2O) produces silicic acid. This

silicic acid forms numerous chemical combinations with alkaline, earthy, and metallic bases termed silicates. The following are the formulæ of certain of the silicic acids (*see* p. 131) :—

$$SiO_2 + H_2O = H_2SiO_3 = \text{metasilicic acid.}$$
$$SiO_2 + 2H_2O = H_4SiO_4 = \text{orthosilicic acid.}$$

Silicates are decomposed by waters containing carbonic acid, and part of the freed silica is absorbed by those waters and carried in solution by streams to lakes and seas. Here it is secreted by diatoms, radiolarians, and other organisms, to form the hard siliceous parts of their structures which ultimately accumulate and form species of rocks called diatomite, radiolarian chert, etc. Diatoms -from the Greek *diatomos*, cut through, in reference to the appearance of their siliceous skeleton—are unicellular algæ. Radiolaria—a group of Protozoa, from the Latin *radiolus*, a little ray—so called from their ray-like appearance.

(1) **Diatomite.** Locality, Aberdeenshire.

A white, chalky-looking rock, soft in consistency and low in specific gravity. When touched it leaves a powdery mark on the fingers. It does not effervesce with hydrochloric acid, and consists essentially of the hard siliceous shelly coverings or frustules of diatoms, which are deposited in both lakes and seas. This rock is also known as ' tripoli powder.'

(2) **Earthy Diatomite.** Locality, Aberdeenshire.

A rough, grey, fine-grained, porous-looking rock of low specific gravity. It can be easily scratched with the finger-nail and it is not decomposed by hydrochloric acid. It consists chiefly of diatom shells or frustules mixed with a quantity of fine sand or mud.

(3) **Earthy Diatomite.** Locality, Isle of Lewis.

A fine-grained, grey-looking rock of low specific gravity. It can be readily marked with the finger-nail, and it does not effervesce with hydrochloric acid. It is made up essentially of diatom remains mixed with very fine sand or mud.

(4) **Radiolarian Chert.** Locality, Portmore, Peebles.

A fine-grained, compact, dark-grey rock which cannot be scratched with a knife and which is not affected by hydrochloric acid. It is composed of minute radiolarian remains cemented together with siliceous deposit + some fine mud as an impurity.

(5) **Siliceous Sinter.** Locality, New Zealand.

A very fine-grained, white and grey rock of uneven structure which can be scratched with a knife and which does not respond to hydrochloric acid. Algæ play an active part in depositing silica. The silica forms a gelatinous layer upon the algous growths, and when the algæ die the silica hardens into the form of siliceous sinter. Sinter—from the German *sinter*, dross.

II. Rocks derived from Plant Remains

Where there have been accumulations of vegetable debris, whether from plant growth *in situ* or from drifts from distant parts, and where these accumulations have been protected from atmospheric action, and consequently where oxidation has been limited, chemical changes have taken place in the vegetable matter which have produced abundant compounds of the hydrocarbon group, especially of the paraffin series. This type of decomposition has resulted in the formation of carbonaceous and coal deposits.

The active agents in this process are anærobic bacteria, and such formations take place most readily where the vegetable material is under stagnant water and where the temperature is low. Anærobic—from the Greek *an*, not, +*aer*, air, +*bios*, life—a term applied to bacteria that can live in surroundings without air or oxygen.

The various types of coal may be divided into three groups, viz. :—

(1) **Sapropelic group**—containing cannel coal and Boghead or torbanite coal. This type of coal has a large proportion of volatile constituents. The percentage of carbon is about 80·0, hydrogen about 5·5, oxygen and nitrogen about 10·2. The ash percentage is fairly high—about 2·7.

Sapropelic—from the Greek *sapros*, decayed or rotten—a term used for a gelatinous or slimy quantity of decomposing animal or vegetable matter found in quiet or stagnant waters.

(2) **Humic group,** also termed bituminous—containing common or house coal and steam coal. There is a fair proportion of volatile ingredients in this type of coal. The percentage of carbon is about 83·5, hydrogen about 6·7, oxygen and nitrogen about 9·6. The ash percentage is low—about 0·20.

Humic, pertaining to or derived from mould—from the Latin *humus*.

(3) **Anthracitic group** containing anthracite. The proportion of volatile matter in this type is small. The carbon percentage is about 91·5, hydrogen about 3·4, oxygen and nitrogen about 2·8. There is a moderate ash percentage—about 1·5.

Anthracitic—from the Greek *anthrax*, *anthrakos*, coal or charcoal.

Speaking generally, the differences in the physical and chemical characters of coals are chiefly due to the differences in the plants which formed the mother substance : or, which is the same thing, 'The nature of the vegetation comprising the mother substance determines the type of coal, and that sapropelic, humic, and anthracitic coals have originated from accumulations, quite distinct from one another, as regards the kind of plant debris in each case.' (Arber, *Natural History of Coal.*)

(1) **Peat.** Locality, Leadburn.

A dark grey-brown, fibrous-looking material with low specific gravity. It is composed chiefly of vegetable debris more or less compressed and decomposed + some earthy impurities.

(2) **Torbanite.** Locality, New South Wales.

A hard, black, fine-textured rock devoid of lustre. It has a clean surface and it breaks with a somewhat conchoidal, slaty fracture. It is composed essentially of compressed, decomposed plant debris including spores, pollen, algæ, etc.

(3) **Cannel.** Locality, Joadja Creek, New South Wales.

A very fine-textured, black, pitchy-looking rock with dull surfaces and breaking with a conchoidal fracture. It is hard but can be scratched with a knife, and it does not soil the fingers. In composition it is similar to number 2, but the process of decomposition has been carried further. A variety of this coal crackles or chatters when burned, hence the name 'parrot coal.'

(4) **Coal.** Locality, Gretna, New South Wales.

A fine-textured, compact, dull, black-looking rock with a tendency to split in layers. It is easily fractured, frequently breaking into somewhat rectangular lumps ; it can be readily marked with a knife and it soils the fingers. It is composed essentially of compressed and decomposed carbonaceous matter.

(5) **Bituminous Coal.** Locality, Blackrack, Gumbles, New South Wales.

A fine-textured, compact, black rock, with resinous lustre. It is readily broken with a crumbling fracture and can be easily marked with a knife. It is composed chiefly of compressed and decomposed vegetable debris.

(6) **Semi-bituminous Coal.** Locality, New South Wales.

Similar to number **5** but the resinous lustre is less marked.

(7) **Iridescent Coal.** Locality not known.

A fine-grained, compact, black-looking rock with a beautiful iridescent lustre, due to a thin film of tarnish on the surface.

(8) **Resinous Coal.** Locality, New Zealand.

A fine-grained, black, compact rock with shining surfaces. Throughout the specimen there are deposits of kauri gum.

(9) **Anthracite.** Locality, Banknock, Stirlingshire.

A lump of hard, black, fine-textured rock with a bright, shining, metallic-looking surface. It breaks with a conchoidal fracture and it does not soil the fingers.

(10) **Bituminous Shale.** Locality, Midlothian.

A very fine-grained compact specimen, splitting in layers and polished on both sides—slicken-sided. It is composed of fine sand or mud containing abundant bituminous matter or hydrocarbons derived from the decomposition of organic matter.

B. CHEMICALLY FORMED ROCKS. Case C

(a) *Calcareous*

Most natural waters contain a small amount of calcium carbonate in solution. The quantity in solution is markedly increased by the presence of free carbonic acid (CO_2) in the water. When this water percolates the crustal rocks, carbonic acid converts the carbonate of lime into the bicarbonate, which is more soluble than the carbonate.

$$CaCO_3+CO_2+H_2O=CaH_2(CO_3)_2.$$

The bicarbonate is not a stable compound, and when the solution containing it is relieved of pressure and exposed to evaporation at the surface, it loses carbonic acid and again becomes carbonate.

But the carbonate is less soluble than the bicarbonate, and part of it is thrown down as a whitish precipitate. In this manner some waters—especially hot springs—deposit great masses of calc sinter or travertine, as in the famous travertine deposits of Tivoli. Travertine—from the Italian *travertino*, an altered form of *tiburtino* from *Tibur*, the old name of Tivoli. Sometimes carbonate of lime is deposited from water by the action of algæ.

(1) **Travertine.** Locality, Rome.

A greyish-white, fine-grained, heavy rock with some small pores opening on the surface. On the upper part of the specimen there is a concentric structure resembling the oölitic or pisolitic texture of limestone. It can be scratched with a knife and it effervesces with hydrochloric acid. Pisolitic—from the Greek *pisos*, a pea—grains about the size of peas.

(2) **Calcite—Deposit.** Locality not known.

A greyish crystalline mass enclosing deposits of fine sand or mud. The crystals show cleavage, they can be scratched with a knife, and they effervesce when treated with hydrochloric acid.

(3) **Aragonite.** Locality, Gibraltar.

A fine-grained, brownish, compact rock with concentric brownish bands varying in depth of colour. The fractured surface is uneven and has a somewhat resinous lustre. It can be scratched with a knife and it effervesces on the application of hydrochloric acid.

Iron pyrites or iron sulphide forms a constituent of many rocks, and when it weathers or decomposes one of the products formed is sulphate of iron. This compound is soluble in water and is carried away in the percolating streams. When this water comes in contact with rocks containing carbonate of lime, a reaction takes place in which sulphate of lime or gypsum is formed. Now sulphate of lime is only sparingly soluble in water and part of it is precipitated as crystals of gypsum. Or again, by evaporation of water containing sulphate of lime in solution, gypsum may be precipitated in layers or beds, as in those beds which have been deposited in inland seas in past geological ages.

(4) **Gypsum—Sulphate of Lime.** Locality, New Zealand.

A translucent ice-like specimen with fibrous crystalline texture. It does not react to hydrochloric acid and it can be scratched with the finger-nail. In some positions it has an iridescent lustre.

(b) *Siliceous*

Silica in the form of quartz is almost wholly insoluble in water, but amorphous and other forms of silica are soluble to a considerable extent in waters containing alkaline carbonates. The quantity held in solution is increased by pressure and by temperatures above normal, consequently when hot springs and other waters of deep-seated origin reach the surface where pressure is diminished, where cooling and evaporation take place, where the influence of algæ and the chemical reaction between different waters come into play, much of the dissolved silica is deposited in masses as siliceous sinter. Geysers in volcanic districts afford examples of such deposits.

(5) **Siliceous Sinter—Geyserite.** Locality, New Zealand.

This is a fine-grained specimen composed of radiating lath-like white bands with a faint tinge of yellow in some parts. It can be readily scratched with a knife and it does not react to hydrochloric acid.

Cherts and flints are composed chiefly of amorphous and chalcedonic quartz. The dark colour is due to impurities, mainly carbonaceous in origin. Probably flints and cherts are due partly to organic and partly to chemical origin. Organisms secrete soluble silica from sea-water to form hard coverings and skeletons. When these organisms die additional fresh silica is added to the hard siliceous remains which give rise to flinty nodules and deposits.

(6) **Chert.** Locality, Isle of Wight.

A very fine-grained compact grey rock which breaks with a conchoidal fracture. It cannot be scratched with a knife and it does not respond to hydrochloric acid. In the specimen there are several small pieces of calcite embedded in the ground-mass. They can be marked with a knife and they effervesce with hydrochloric acid. One end of the specimen is covered with a hard, white, porcellanous-looking crust.

(7) **Flint.** Locality, Isle of Wight.

There are two specimens. One is a nodular mass covered with a white, very fine-grained, porcellanous-looking crust, which cannot be scratched with a knife and does not react to hydrochloric acid. On the surface there are numerous small pores. The other specimen is a broken flint nodule showing conchoidal

fracture. It is a very fine-grained, hard, compact, dark-grey rock with a few roundish lighter-coloured patches in the ground-mass. It does not react to hydrochloric acid.

(c) *Ferruginous*

Water frequently contains carbonic acid and other acids derived from the decomposition of animal and vegetable matter. When this percolates through the crustal rocks it decomposes iron compounds which are constituents of these rocks, and carries off part of the iron in solution as carbonates and salts of the organic or humic acids. When this water again reaches the surface and comes into contact with the atmosphere the iron-bearing solutions become oxidised and iron is precipitated in the form of oxides or hydroxides, forming deposits of iron in springs, streams, and lakes.

Formula—$H_2Fe(CO_3)_2=FeCO_3+CO_2+H_2O$. Further oxidation produces ferric hydrate thus—

$$2FeCO_3+O+H_2O=Fe_2O_3 \cdot H_2O+2CO_2.$$

In some cases iron is separated from its solutions by the action of vegetable matter, either directly or indirectly. This process, which is a complex one, takes place in lakes and marshes, and results in the precipitation of hydrated oxides of iron—limonite, bog-iron ore, etc.

(8) **Iron Ore—Blackband.** Locality, Ayrshire.

A fine-grained, heavy, compact, brown-coloured rock with laminated structure. The laminæ vary in thickness and in depth of colour. It contains some very fine-grained sand or mud as an impurity.

(9) **Iron Ore—Septarian Nodule.** Locality, Derbyshire.

A mass of clay ironstone in the form of a large nodule which is cracked internally. The cracks are small at the circumference, increase in size towards the centre, and are filled with a deposit of cream-coloured calcite.

Septarian—so-called from the *septa*, *i.e.* compartments formed by the cracks.

(10) **Iron Ore—Clay Ironstone.** Locality, Carluke.

There are two specimens of clay ironstone. The larger one is a fine-grained, heavy, roundish, black-coloured rock which gives a black streak when scratched with a knife. The smaller specimen is a shell of clay ironstone enclosing a pebble. It is dark-brown in colour and very hard.

C. METAMORPHIC ROCKS. Case C

Rocks which compose the lithosphere do not always remain as they were first formed, but some of them undergo various kinds of alterations which confer on these rocks characters different from the characters they originally possessed. A change of this kind is called metamorphism, and the rocks so affected are termed metamorphic rocks. Lithosphere—from the Greek *lithos*, a stone, +*sphaira*, a sphere—meaning the stone sphere or the crust of the earth. Metamorphism—from the Greek *meta*, after (denoting change), +*morphe*, a form—change of form or structure.

Rocks of this class are for the most part crystalline and they possess a peculiar form of structure called foliation. Foliation—from the Latin *folium*, a leaf—leaf-like structure. This foliated structure consists in the more or less parallel arrangement of the various constituents of which the rock is composed. Each layer may be composed of one kind of mineral only, or of two or more intermingled. The layers or folia are usually lenticular in form, but this foliated structure varies considerably. Sometimes the layers are fairly even and parallel, resembling lamination; at other times the folia thicken and thin out somewhat abruptly, or these conditions may alternate. Foliation is the result of high pressure induced by crustal movements, and it is always accompanied by the more or less complete recrystallisation of minerals, or the formation of new ones. Rocks formed by this process are known as gneisses and schists, and they may be produced from either igneous or sedimentary rocks.

Speaking generally, the difference between a gneiss and a schist is one of degree in texture. The coarse-grained rocks with thick folia are termed gneisses, and the fine-grained rocks with thin folia are termed schists. Gneiss—the *German name* for a foliated rock similar to granite in composition. Schist—from the Greek *schistos*, divided or split.

(a) *Gneiss and Schist*

(1) **Archean Gneiss.** Locality, Ross-shire.

A coarse-grained, crystalline, greenish-black rock, with pinkish-brown and pale-grey folia running transversely to length of specimen.

(2) **Archean Gneiss.** Locality, Ross-shire.

A coarse-grained, foliated, crystalline rock, with the folia dark-green, pale-grey, and pinkish-brown in colour.

(3) **Gneiss.** Locality, Aberdeenshire.

A medium-grained, coarsely foliated, crystalline rock. The folia vary in colour from greenish to pale-grey with brownish tinge.

(4) **Gneiss.** Locality, Iona.

A coarse-grained, crystalline, foliated rock. The folia are alternately purplish brown and grey.

(5) **Lewisian Gneiss.** Locality, Western Isles.

A coarse-grained, crystalline rock with lenticular folia alternately pinkish-brown and grey. There are two specimens—one polished, the other unpolished.

(6) **Augen Gneiss.** Locality, Banff.

A coarse-grained, crystalline, grey rock. The folia thicken here and there with roundish aggregates of quartz or felspar which give an eye-like appearance to the rock—hence augen gneiss.

Augen—the German for eyes.

(7) **Banded Gneiss.** Locality, Cornwall.

A medium-grained, crystalline rock with banded texture. The bands vary in colour; some are brownish, others are greenish-grey, and others again are pale greenish-grey.

(8) **Gneiss.** Locality, Banff.

A very coarse-grained, crystalline rock, speckled black and white in colour, and showing foliated structure.

All the above specimens of gneiss in regard to chemical composition and mineral constituents very much resemble members of the granite group.

(9) **Hornblende Gneiss.** Locality, Iona.

A coarse-grained, crystalline, dark-green rock. It shows foliated structure, and hornblende is the dominant mineral.

(10) **Gneiss.** Locality, Craigellachie, Banffshire.

A medium-grained, crystalline, greyish rock, banded in structure. The bands vary in depth of colour.

(11) **Schistose Gneiss.** Locality, Wigtownshire.

A coarse-grained, crystalline, mottled white and dark-green rock. The folia are thin and schist-like.

(12) **Chloritic Schist.** Locality, Grampians.

A fine-grained, green and grey rock with foliated structure and dominant chlorite.

(13) **Mica Schist.** Locality, Perthshire.

A fine-grained, silvery-looking rock, with foliated structure and dominant muscovite.

(14) **Garnetiferous Schist.** Locality, Aberdeenshire.

A coarse-grained, silvery-looking rock, foliated in structure, with muscovite and garnets as dominant minerals.

(15) **Schist.** Locality not known.

A fine-grained, dark-grey, crystalline rock with foliated structure ; the folia run nearly parallel.

(16) **Graphite Schist.** Locality, Iona.

A fine-grained, black-looking rock with some lustre on the surface. It is foliated in structure, soft in consistency, soils the fingers when touched, and marks paper readily. On the surface there are two brownish deposits.

(17) **Greenstone Schist.** Locality, Grampians.

A fine-grained, compact, greyish-green rock showing thin foliated texture.

(18) **Hornblende Schist.** Locality, Caithness.

A coarse-grained, greenish-black coloured rock showing indistinctly thin foliated structure.

(19) **Phyllite.** Locality, Wigtownshire.

A fine-grained, compact, greenish-looking rock with a sinuous banded structure and a fine foliated texture.

(20) **Phyllite.** Locality, Aberdeenshire.

A fine-grained, purplish-grey rock with foliated structure.

(b) *Marble*

When an intrusive mass of magma comes in contact with calcium carbonate—lime deposit—it recrystallises the limestone *in situ.* It does not matter whether the limestone is derived from an organic or an inorganic source, the action is the same—re-crystallisation of limestone or the production of what is called marble. Marble therefore is a crystalline limestone.

The crustal changes which produce crystalline schists also

influence the crystallisation of lime deposits, so that marble beds are often associated with crystalline schists on various geological horizons. In the course of these changes the clay, sand, and other impurities of limestone are also recrystallised and appear as crystalline silicates which give the marble its various tints and colours.

(1) **Granular Marble.** Locality, British East Africa.

A coarse-grained, crystalline white rock which can be marked with a knife and which effervesces with hydrochloric acid. When examined with a lens the crystals show good cleavage and they have an iridescent lustre.

(2) **Iona Marble.** Locality, Iona.

A fine-grained, compact rock, whitish in colour with a greenish-grey mottling.

(3) **Marble.** Locality, from the Temple of Jupiter, Athens.

A white granular rock of medium-grained texture which is readily marked with a knife, and which decomposes on the application of hydrochloric acid.

(4) **Marble.** Locality, Sutherlandshire.

A fine-grained, softish, crystalline, white rock which reflects light strongly and effervesces with hydrochloric acid.

(5) **Banded Marble.** Locality, from Temple of Jupiter, Athens.

A fine-grained, compact rock, banded in structure with white and pale-brown bands.

(6) **Marble.** Locality, Glen Tilt.

A fine-grained, crystalline, compact rock, mottled pale-grey and greenish-grey, which effervesces freely with hydrochloric acid.

(7) **Marble.** Locality, Tyrol.

A fine-grained, compact, crystalline rock, mottled dark-grey, pale-grey, and white, which effervesces freely with hydrochloric acid.

(8) **Marble.** Locality, Italy—from Pompeii.

A fine-grained, crystalline, compact rock, mottled white and pale-grey, which effervesces freely with hydrochloric acid.

(c) *Serpentine*

Formerly serpentine was looked upon as a distinct mineral, but it is now generally considered as a secondary product, resulting from the alteration of magnesium-rich minerals and rocks,

especially those which belong to the olivine group. Such rocks are prone to alteration in the process of weathering, and by the absorption of water the magnesium silicate becomes a hydrated magnesium silicate or serpentine. The colour of serpentine varies much. It may have various shades of green, or it may have a yellowish or a red colour. The distribution of colour is irregular, and there is often mottling and veining like the skin of a serpent—hence the name serpentine.

(1) **Precious Serpentine.** Locality, Cornwall.

A compact, reddish-brown and pale-green rock, highly polished on one surface. It has a somewhat oily- or greasy-looking appearance.

(2) **Common Serpentine.** Locality, Cornwall.

A compact, fine-grained, heavy rock, reddish-brown in colour. It is in its natural state.

(3) **Serpentine.** Locality, Cornwall.

A fine-grained, compact rock which is a specimen of red serpentine in its natural state.

(4) **Serpentine.** Locality, Cornwall.

A fine-grained, compact rock—a specimen of black serpentine in the natural state.

(5) **Chrysotile Serpentine.** Locality, Cornwall.

A heavy, compact rock, mottled light and dark-green, with a foliated scaly appearance due to the formation of chrysotile as a secondary product.

Chrysotile—from the Greek *chrysos*, gold; *chrysites*, golden.

(6) **Serpentine.** Locality, Cornwall.

A polished specimen of grey precious serpentine.

(7) **Variegated Serpentine.** Locality, Cornwall.

A specimen of serpentine of various colours.

(8) **Serpentine.** Locality, New Zealand.

A fine-grained, heavy, pale-green, compact rock, scaly in appearance, which cannot be scratched with a knife and which does not effervesce with hydrochloric acid. This is a specimen of Maori greenstone, sometimes called serpentine marble.

(9) **Serpentine.** Locality, New Zealand.

A dark-green, heavy, compact rock, scaly in appearance, which

can be scratched with a knife with difficulty and which does not effervesce with hydrochloric acid. This is another specimen of Maori greenstone or serpentine marble.

(10) **Chrysotile Serpentine.** Locality, Cornwall.

A specimen of serpentine developing or degenerating into chrysotile or fibrous serpentine. The texture is markedly fibrous.

(11) **Chrysotile Serpentine.** Locality, Cornwall.

Two specimens of serpentine decomposing into chrysotile or fibrous serpentine.

(12) **Marmolite Serpentine.** Locality, Cornwall.

A specimen of serpentine showing a small fibro-lamellar mass of cream-coloured marmolite.

Marmolite—from the Greek *marmaros*, marble, +*lithos*, a stone—like marble in appearance.

(13) **Serpentine.** Locality, Cornwall.

A specimen of serpentine near an intrusive mass, showing a baked appearance.

CHAPTER IV

Miscellaneous Collection. Cases D, E, F, G

Case D

This collection consists of a number of rocks, some of which are not only interesting but also uncommon.

(1) * **Core.**

A core from a bore-hole put down in search of coal. This part of the core consists chiefly of lime deposit containing numerous remains of brachiopods and molluscs.

(2) **Core.** Locality, Lanarkshire.

A core cut with a diamond drill from bore-hole put down in search of coal. The core shows a shaly formation with nodules of ironstone.

(3) **Specimen—Large Composite.** Locality, Westmorland.

This specimen consists of (*a*) quartz in white crystals; (*b*) siderite or chalybite—carbonate of iron—in small, flat, brownish-yellow crystals; (*c*) lead sulphide—galena—in large, dark-coloured square-looking blocks. Siderite is from the Greek *sideros*, iron. Chalybite is from the Greek *chalyps*, *chalybos*, steel.

(4) **Micaceous Rock.** Locality, Aberdeenshire.

This rock consists chiefly of crystals of muscovite or white mica.

(5) **Core.** Locality, Lanarkshire.

The core cut with a diamond drill from a bore-hole put down in search of coal. This rock is a shaly sandstone and shows false bedding.

(6) **Arenaceous Ironstone.** Locality, Nubia.

This specimen is a brown, nodular mass of ironstone containing grains of sand which give it a granular appearance.

(7) **Ironstone.** Locality not known.

This rock is a brown, irregular mass of ironstone embedding deposits of clay or mud. Some of these deposits have been weathered out, leaving holes or cavities in the specimen.

(8) * **Micaceous Sandstone.**

The core of a bore through micaceous sandstone.

(9) **Trona.** Locality, British East Africa.

Derivation doubtful, probably of *Arabic origin.*

This specimen consists of a light-brown mass of radiating fibres of the sesquicarbonate of soda found at Lake Magudi, British East Africa.

(10) **Marble.** Locality, British East Africa.

A white compact mass of marble which is used in British East Africa as hydraulic lime.

(11) **Shelly Limestone.** Locality not known.

A white mass with a pale tinge of pink composed chiefly of decomposing shells.

(12) **Dolerite** containing **Chlorophæite.** Locality, Ravelrig Quarry, Midlothian.

Chlorophæite—from the Greek *chloros*, greenish, +*phaios*, dark or dusky—a dark-green.

A dark-coloured, compact rock of quartz-dolerite, containing numerous black shining patches of chlorophæite.

(13) **Bloomery Slag.** Locality, Bonar Bridge.

A brown, irregular piece of iron slag, with numerous cavities opening on the surface, from the smelting furnaces formerly worked in Sutherlandshire.

(14) **Scyelite.** Locality, Invershin, Sutherlandshire.

A heavy, compact rock, dappled pinkish-brown, black, and green, composed chiefly of hornblende, biotite, and olivine, with well-marked poikilitic structure—that is, a structure due to the inclusion of rounded olivines in larger crystals of other minerals.

Scyelite takes its name from *Loch Scye*, Sutherlandshire.

(15) **Sapphire-bearing Xenolith.** Locality, Mull.

Xenolith—derived from the Greek *xenos*, a stranger, +*lithos*, a stone—a stone included as fragments in other stones. This specimen consists of fragments of sedimentary rocks embedded in basalt. It contains numerous crystals of deep-blue sapphire.

(16) **Pegmatite.** Locality, Aberdeenshire.

A specimen of large- or giant-grained granite associated with acid-magma intrusions.

(17) **Hornblende-Porphyrite.** Locality, Mull of Galloway.

A rock with a brownish-grey crystalline matrix in which are embedded phenocrysts of felspar (plagioclase) and dark-green hornblende.

(18) **Melanite-Syenite.** Locality, Loch Borolan.

This specimen of felspathic rock is grey in colour and is spotted with small black crystals of melanite or black (calcium-iron) garnet. It is really a felspathic melanite-syenite.

(19) **Pipe Rock.** Locality, Ben More, Assynt.

A compact, brownish-green tinged rock with roundish white markings on the surface. These markings are the tracks of worms or annelids, which are filled with a deposit of silica. The name is derived from the *tubes* or *pipes* in the rock. It is a Cambrian quartzite.

(20) **Chert.** Locality, Rhynie, Aberdeenshire.

A specimen of Rhynie chert containing some remarkably well-preserved fossils of plants. They are distinctly seen on the polished surface.

(21) **Malachite Vein.** Locality, Kirkcudbrightshire.

A specimen of rock through which runs a greenish vein of malachite (carbonate of copper).

(22) **Calcite.** Locality not known.

A specimen of calcite on which are developed crystals of tremolite.

(23) **Zoisite.** Locality, Aberdeenshire.

So named by Werner after *von Zois*, from whom he received a specimen.

Zoisite is a hydrated silicate of calcium and aluminium. It occurs in lime-rich rocks which have undergone metamorphism. The specimen exhibited is pale greenish-grey in colour.

(24) **Marble.** Locality, Cnoc-na-Sroine, Assynt.

A pale-grey rock with faint yellowish tinge, consisting of crystallised Cambrian limestone—Durness limestone.

(25) **Forsterite-Marble.** Locality, Ben More, Assynt.

A greenish-coloured rock with yellowish tinge, consisting of crystallised Cambrian magnesian limestone—Durness limestone.

(26) **Limestone.** Locality, Ben More, Assynt.

A rock whose component parts are coloured pale-pink, brown, and silvery white. It is an altered Cambrian limestone—Durness limestone.

(27) **Calc Sinter.** Locality not known.

A specimen of calc sinter—carbonate of lime—greyish-white in colour with radiating fibres. It is also known as travertine.

(28) **Quartz-Syenite.** Locality, Loch Borolan, Sutherlandshire.

A hard, crystalline, pale pinkish-brown rock from the top of the syenite mass of Cnoc-na-Sroine.

(29) **Syenite.** Locality, Loch Borolan.

A reddish-brown holocrystalline rock from the middle of the syenite mass of Cnoc-na-Sroine.

(30) **Ledmorite.** Locality, Loch Borolan.

A brownish to greenish-grey holocrystalline rock from the base of the syenite mass of Cnoc-na-Sroine. It is composed essentially of orthoclase, altered nepheline, melanite, ægirine-augite, and biotite. So named from the place-name *Ledmore*, Assynt, Sutherland.

(31) **Cromaltite.** Locality, Loch Borolan.

A dark-coloured, basic-looking, compact, crystalline rock, composed chiefly of ægirine-augite, melanite, and biotite. It takes its name from the *Cromalt Hills*, Assynt, Sutherland.

(32) **Hybrid Rock.** Locality, Loch Borolan.

The constituent parts of this rock are coloured white, pink, and dark green. It is a hybrid rock, and apparently formed by the invasion of cromaltite by a felspathic liquor.

(33) **Borolanite.** Locality, Loch Borolan.

A heavy, compact, grey rock, with roundish white masses or spots. The dark-grey matrix consists of orthoclase and melanite with subordinate green biotite. The white spots are chiefly orthoclase, muscovite, and zeolitic material, or sometimes almost entirely orthoclase. Some authorities consider these white spots to be pseudoleucites—orthoclase crystals, etc., replacing leucite crystals. The name is derived from the place-name *Loch Borolan*.

(34) **Borolanite.** Locality, Loch Borolan.

Similar to (33), but the crystals of orthoclase are pinkish instead of white.

(35) **Oölitic Ironstone.** Locality, Northamptonshire.

A brown rock of oölitic structure where the oölitic calcium carbonate has been replaced by the carbonate of iron or chalybite. The specimen is from Jurassic limestone.

(36) **Conglomerate.** Locality, Leadburn.

A hard, dark-greyish coloured rock, composed of various kinds of pebbles bound together by a calcareous cement. Locally this is known as 'haggis rock.'

(37) **Copper Nodule.** Locality, Kent.

A brownish, irregular, heavy nodule with projecting jagged edges on one surface round an opening which communicates with a hollow interior. When the brown chocolate-coloured deposit is removed a coppery metallic lustre is displayed.

(38) **Quartz.** Locality, Galloway.

This rock is speckled green, brown, and white. The green constituents are copper, the brown constituents are iron, the white constituents are crystals of quartz. The specimen consists chiefly of copper and iron on quartz.

(39) **Hornblende-Porphyry.** Locality, Galloway.

A brown-coloured compact rock, the matrix of which consists chiefly of felspar (orthoclase) and hornblende. In the matrix are embedded phenocrysts of dark-green hornblende.

(40) **Garnetiferous Amphibolite.** Locality, Killiecrankie.

A dark-coloured, medium-grained, compact rock. The matrix is composed essentially of felspar and hornblende, and embedded in it are numerous, reddish-coloured almandine garnets.

(41) **Argentiferous Gossan.** Locality, Australia.

A yellowish-brown, rusty-coloured rock which contains a small percentage of silver.

Gossan is derived from the old Cornish word *gozzan* which means an old wig grown yellow from age and wearing. In mining the term is applied to the ferruginous quartzose material which often forms the outcrop of a lode. This outcrop frequently contains among other things metallic sulphides, especially the sulphides of

iron. These sulphides become oxidised, and the brownish-yellow oxide of iron remains mixed with the gangue—the non-metallic part of the lode. This rusty-brown material is the gossan of the Cornish miner (*Cent. Dict.*).

(42) **Calcite.** Locality, Bicester, Oxfordshire.

A pale-grey rock with a very slight violet tinge, known locally as 'cream cheese.' It forms the top of the Great Oölite, Blackburn Hill, and is composed chiefly of carbonate of lime.

(43) **Talc.** Locality not known.

This is a specimen of talc, brown, green and white in colour. It has a pearly lustre and a greasy feel. In chemical composition it is a hydrous silicate of magnesium. It is a secondary product, generally replacing non-aluminous magnesian silicates.

(44) **Calcite.** Locality, Australia.

A grey compact rock composed chiefly of carbonate of lime, showing cylindrical openings and perforations made by boring molluscs. Locally it is known as 'Gow's ballast.'

(45) **Hematite.** Locality, Dalbeattie.

A specimen of hematite from a thin vein of iron associated with an intrusive dyke.

(46) **Chert on Lava.** Locality, Whitemuir, Leadburn.

This specimen shows the line of union between chert and lava. The lava was poured out over the bed of the ocean, and the chert was afterwards deposited on the surface of the lava.

(47) **Breccia.** Locality, Winkstone, Peebles.

This rock consists of angular fragments of various kinds of rock cemented together by calcareous material.

(48) **Pillow Lava.** Locality, Noblehouse Quarry.

So called pillow lava from the manner in which the masses of lava seem to be rolled up like pillows. It is a dark greyish-green, compact, basic-looking rock.

(49) **Basic Lava.** Locality, Lanarkshire.

A dark-coloured, heavy, compact, basaltic-looking rock consolidated from a basic magma.

(50) **Acid Lava.** Locality, Hamilton Hill, Peebles.

A grey compact rock with a tinge of green in the matrix and embedded in which are a few phenocrysts. This lava represents an acid magma.

Rock magmas consist of silica together with the bases, iron oxides, alumina, lime, magnesia, potash, and soda. If the silica is much in excess of the bases, the solidified rocks contain free silica or quartz, and such rocks are said to be ‘ acid rocks.’ If, on the other hand, the silica percentage is low, the rocks are said to be ‘ basic rocks.’

(51) **Mudstone.** Locality, Noblehouse.

A brown, chocolate-coloured rock with a matrix of very fine sand or mud impregnated with iron.

(52) **Limestone.** Locality, Hamilton Hill, Peebles.

A heavy, compact rock, mottled dark and light grey, consisting essentially of carbonate of lime.

(53) **Chert.** Locality, Portmore, Peebles.

A specimen of chocolate-coloured radiolarian chert.

(54) **Chert.** Locality, Riddenlees, Peebles.

A specimen of flint-coloured radiolarian chert.

(55) **Core.** Locality, Norfolk.

The core from a bore-hole, showing various kinds of fossils in a Lias stratum.

(56) **Collection.** Locality, Mont Blanc.

A collection of 140 different rocks and fossils found in Mont Blanc. The various specimens are all numbered and named.

Case E

(57) **Apatite.** Locality, Canada.

For description, see ‘ Rock-forming Minerals,’ p. 16.

A very large, pale-green coloured crystal of apatite or phosphate of lime. It shows the six-sided or hexagonal prism with pyramidal ends which are broken.

(58) **Calcite in Greywacke.** Locality, Peebles.

A weather-worn greywacke in the fissures of which there is a very pale pinkish-white deposit of calcite.

(59) **Basic Lava.** Locality, Lanarkshire.

A dark-coloured, heavy, basic-looking rock, compact in structure and augitic in composition. On some parts of the surface there is a white, shining deposit of calcite.

(60) **Gabbro.** Locality, Skye.

A heavy, compact, greenish-looking rock, consisting essentially of basic plagioclase and diallage.

(61) **Argentiferous Rock.** Locality, Nevada, U.S.A.

A greyish-brown rock with an irregular surface showing a few shining crystals of pyrites. This rock contains a percentage of silver.

(62) **Monchiquite.** Locality, Colonsay.

A dark-coloured, fine-grained, very basic rock consisting essentially of olivine, augite, and analcite. In the fine-grained matrix there are numerous large, black crystals of biotite. Named in reference to the place-name *Serra de Monchique*, Portugal.

(63) **Muscovite.** Locality, New Zealand.

A beautiful specimen of potash or white mica, showing planes of cleavage.

(64) **Diorite.** Locality, Ross Island (Galloway).

A fine-grained, compact, greenish-brown rock composed essentially of plagioclase and hornblende.

(65) **Hornblende-Porphyry.** Locality, Kirkcudbright.

A compact, brownish-coloured rock composed essentially of orthoclase, mica, and quartz. In the matrix there are numerous large crystals of dark-green hornblende.

(66) **Hornblende-Porphyrite.** Locality, Innerleithen.

A heavy, solid rock of pale pinkish-brown colour in the fine-grained matrix of which are crystals of plagioclase and hornblende. There are two specimens on the tray, one polished and the other unpolished.

(67) **Breccia.** Locality, Loch Torridon.

A hard, solid rock, pale-grey and brown in colour, composed of sand and fragments of rock, more or less banded in structure and cemented together with silica.

(68) **Shelly Limestone.** Locality, Wrae Quarry, Peebles.

Two greyish-coloured specimens of limestone rock containing fossil shells.

(69) **Pitchstone.** Locality, Arran.

A piece of black, shining, resinous-looking rock from a lava flow. It shows conchoidal fracture.

(70) **Felsitic Lava.** Locality, Winkston.

A mass of reddish-brown rock, compact in structure, the matrix of which is a fine-grained, crystalline aggregate, composed largely of felspar microlites.

(71) **Hemimorphite.** Locality, Leadhills.

On a mass of zinc blende there are numerous roundish, white deposits, varying in size and composed of the silicate of zinc or hemimorphite.

(72) **Smithsonite.** Locality, Wanlockhead.

An irregular, white, crystalline deposit, consisting of carbonate of zinc or smithsonite.

(73) **Lugarite.** Locality, Ayrshire.

A dark-coloured, porphyritic rock containing phenocrysts of dark augite and the soda-amphibole barkevicite, with small and variable amounts of labradorite-felspar, in a ground-mass of analcite with traces of nepheline.

(74) **Microcline.** Locality, Switzerland.

A beautiful crystal of microcline-felspar, greenish in colour, known as 'Amazon stone.'

The next series is a collection of economic rocks from Ontario, Canada. Descriptions of similar rocks are given under 'Rock-forming Minerals and Mineralogy.'

(75) **Pyrites or Pyrite.** Locality, Tweed, Ontario.

Disulphide of Iron—FeS_2.

See Sulphides—Case 1.

(76) **Arsenopyrites or Mispickel.** Locality, Deloro.

Sulpharsenide of Iron—FeAsS.

This specimen also contains a small percentage of gold. See Sulphides—Case 1.

(77) **Chalcopyrites or Copper Pyrites.** Locality, Mine Centre.

Sulphide of Copper and Iron—$Cu_2S.Fe_2S_3$.

See Sulphides—Case 1.

(78) **Bornite.** Locality, Parry Sound.

Sulphide of Copper and Iron—Cu_3FeS_3.

See Sulphides—Case 1.

(79) **Chalcocite.** Locality, Parry Sound.

Sulphide of Copper—Cu_2S.

See Sulphides—Case 1.

(80) **Pyrrhotite.** Locality, Sudbury.

Ferrous Sulphide—Fe_5S_6.

This specimen also contains a percentage of nickel. Pyrrhotite

is usually in massive form with granular structure. The fracture is uneven and the lustre is metallic. The colour is between bronze-yellow and copper-red, and it tarnishes on exposure to light. The hardness is from 3·5 to 4·5 in the scale, the sp. gr. is 4·6, and it possesses magnetic properties.

(81) **Magnetite.** Locality, Frontenac.
Protoxide + Sesquioxide of Iron—$FeO.Fe_2O_3$.
See Rock-forming minerals—Case A.

(82) **Ilmenite.** Locality, Bancroft.
Oxide of Iron which contains titanium—$FeO.TiO_2$.
Also called titanic iron ore.
See Rock-forming minerals—Case A.

(83) **Red Hematite.** Locality, Hastings Co.
Sesquioxide of Iron—Fe_2O_3.
See Rock-forming minerals—Case A.

(84) **Hematite.** Locality, Lanark Co.
Sesquioxide of Iron—Fe_2O_3.
See Rock-forming minerals—Case A.

(85) **Limonite—Bog Iron Ore.** Locality, Fort William.
Hydrated Sesquioxide of Iron—$2Fe_2O_3.3H_2O$.
See Rock-forming minerals—Case A.

(86) **Limonite—Brown Ore.** Locality, Michipicoten.
Hydrated Sesquioxide of Iron—$2Fe_2O_3.3H_2O$.
See Rock-forming minerals—Case A.

(87) **Siderite or Chalybite.** Locality, Michipicoten.
Protocarbonate of Iron—$FeCO_3$.
See Carbonates—Case 3.

(88) **Auriferous Quartz.** Locality, Porcupine.
Gold in Quartz.
See Native elements—Case 1.

(89) **Silver.** Locality, Cobalt.
This specimen is an argentiferous calcite.
Silver. See Native elements—Case 1.

(90) **Smaltite.** Locality, Cobalt.
Diarsenide of Cobalt—$CoAs_2$.
See Sulphides—Case 1.

(91) **Niccolite.** Locality, Cobalt.
Arsenide of Nickel—NiAs.
See Sulphides—Case 1.

(92) **Breithauptite.** Locality, Cobalt.
Antimonide of Nickel—NiSb.

This mineral is sometimes found in hexagonal crystals, but it is usually in massive, arborescent form. The sp. gr. is 7·5, and the colour is light copper-red.

(93) **Galena.** Locality, Galetta.
Sulphide of Lead—PbS.
See Sulphides—Case 1.

(94) **Zinc Blende or Sphalerite.** Locality, Zenith Mine.
Sulphide of Zinc—ZnS.
See Sulphides—Case 1.

(95) **Graphite or Plumbago.** Locality, Calabogie.
Composed simply of the element carbon.
See Native elements—Case 1.

(96) **Molybdenite.** Locality, North Renfrew.
Sulphide of Molybdenum—MoS_2.
See Sulphides—Case 1.

(97) **Mica.** Locality, Frontenac.
Silicate of Aluminium and Potassium—$H_2KAl_3(SiO_4)_3$.
See Rock-forming minerals—Case A.

(98) **Felspar.** Locality, Frontenac.
Plagioclase series (*see* p. 7).
See Rock-forming minerals—Case A.

(99) **Apatite.** Locality, Frontenac.
Essentially a phosphate of lime.
See Rock-forming minerals—Case A.

(100) **Sodalite.** Locality, Bancroft.
Silicate of Aluminium and Sodium.
See Rock-forming minerals—Case A.

(101) **Corundum.** Locality, Combermare.
Oxide of Aluminium—Al_2O_3.
See Oxides—Case 2.

(102) **Gypsum.** Locality, Caledonia.
Hydrous Sulphate of Calcium—$CaSO_4 . 2H_2O$.
See Sulphates—Case 4.

(103) **Gypsum—Selenite.** Locality, Kingdon Lead Mine.
This specimen is the clear, transparent form of gypsum termed selenite.
See Sulphates—Case 4.

(104) **Barite or Barytes.** Locality, Langmuir Mine.
Sulphate of Barium—$BaSO_4$.
See Sulphates—Case 4.

(105) **Barite or Barytes.** Locality, Madoc.
The same as No. 104.

(106) **Celestite.** Locality, Calabogie.
Sulphate of Strontium—$SrSO_4$.
See Sulphates—Case 4.

(107) **Fluor-spar.** Locality, Madoc.
A chemical combination of lime and fluorine.
See Haloids—Case 1.

(108) **Asbestos.** Locality, Porcupine.
A product of the hornblende family.
See Rock-forming minerals—Case A.

(109) **Talc.** Locality, Madoc.
Hydrated Silicate of Magnesium—$H_2O . 3MgO . 4SiO_2$.
See Silicates—Case 4.

(110) **Marble.** Locality, Bancroft.
Crystalline limestone.
See Metamorphic rocks—Case C.

Case F

(111) **Diallage-Rock.** Locality, Skye.

A coarse-grained, greenish-grey, crystalline rock, composed chiefly of diallage, showing a somewhat foliated structure.

(112) **Amphibolite.** Locality, Killiecrankie.

A coarse-grained, crystalline rock, dark in colour with a slight purplish tinge, consisting essentially of felspar and hornblende. In the matrix are embedded numerous crystals of garnet.

(113) **Grano-Diorite.** Locality, Walkerburn, Peebles.

Another holocrystalline rock much weathered on the surface. This type of rock is defined as ' a light-grey, granitic rock in which soda-lime felspars largely predominate over orthoclase, the remaining essential constituents being quartz, biotite, and usually hornblende.'

(114) **Rhyolite.** Locality, South Africa.

A pale-grey coloured igneous rock in the fine matrix of which are numerous large crystals of felspar.

(115) **Greywacke.** Locality, Innerleithen.

A fine-grained, compact greywacke. This specimen was obtained near an intrusive dyke and shows a ' baked ' appearance.

(116) **Felsite.** Locality, Melrose.

A brick-red coloured, heavy rock, the fine matrix of which contains many crystals of felspar. Attached to this rock is a greyish-coloured tuff.

(117) **Rhyolite.** Locality not known.

A greyish-coloured rock showing well-marked flow structure.

(118) **Pitchstone.** Locality, Arran.

A sample of pitchstone showing spherulitic structure.

(119) **Lava.** Locality, New Zealand.

A specimen of dark-coloured pumice-stone.

(120) **Solfataric Sulphur.** Locality, Italy.

Two pale-coloured specimens of sulphur deposits from the Solfatara crater near Naples.

(121) **Garnetiferous Schist.** Locality, Perthshire.

A sample of greyish-coloured mica-schist containing numerous garnets.

(122) **Iona Silver Stone.** Locality, Iona.

This rock consists essentially of altered limestone, serpentine, and mica.

(123) **Limestone.** Locality, Northumberland.

This is a fine-grained rock consisting essentially of carbonate of calcium and fine sand or mud. It is generally known as cementstone.

(124) **Conglomerate.** Locality, Peebles.

A conglomerate rock of ' Old Red Sandstone ' from Whitemuir.

(125) **Breccia.** Locality, Peebles.

A rock composed of angular fragments of various kinds of rocks, cemented together by calcareous material.

(126) **Green Sandstone.** Locality, Isle of Wight.

A specimen of green sandstone containing a few small fossils.

(127) **Flint Nodule.** Locality, Isle of Wight.

A deposit of flint on a fossil which is probably a sponge.

(128) **Diatomite.** Locality, Aberdeenshire.

On this tray are two pale-cream coloured pieces of rock, composed chiefly of the siliceous remains of diatoms. The rock is light in weight, porous in nature, and soils the fingers to touch.

(129) **Hemimorphite.** Locality, Leadhills.

On a zinc base there is a greyish-brown deposit consisting essentially of the hydrated silicate of zinc or hemimorphite.

(130) **Pyromorphite.** Locality, Leadhills.

This specimen shows pale-grey and pale-yellow deposits of pyromorphite (phosphate of lead) and cerussite (carbonate of lead) on a brecciated rock.

(131) **Vesuvianite.** Locality, Italy.

On the surface of a brecciated rock there are numerous brownish-coloured and clear crystals of basic calcium-aluminium silicate or vesuvianite.

(132) **Argentiferous Kaolin.** Locality, New South Wales.

A white and brown mottled-looking rock containing embolite or silver chloro-bromide.

(133) **Manganite.** Locality, New South Wales.

A heavy, black-looking rock with metallic lustre, consisting chiefly of the hydrated sesquioxide of manganese or manganite.

(134) **Perthite.** Locality, Canada.

A white- and brown-mottled specimen, consisting essentially of intergrown orthoclase and albite.

(135) **Calcite.** Locality, Leadhills.

A base of zinc on the surface of which are deposited large crystals of calcite.

(136) **Ironstone.** Locality, Lanarkshire.

This is a specimen of a ferruginous deposit surrounding a softer material which has weathered out, leaving a hollow centre.

(137) **Marl.** Locality, Heligoland.

A rock composed chiefly of calcareous deposits from organic remains. It is soft in texture and can be readily marked with a knife.

(138) **Fossil.** Locality, Whitby.

In this dark-coloured rock are embedded several teeth of ganoid fishes.

(139) **Coal.** Locality, Ayrshire.

A sample of coal showing arborescent markings.

(140) **Pebble.** Locality, Devonshire.

A pebble from the Trias bed, Budleigh Salterton, containing a fossil shell probably of Ordovician age.

(141) **Coral.** Locality, Devonshire.

Syringopora ramulosa—a polished section showing tubular corallites.

(142) **Sponge.** Locality, Devonshire.

Sphærospongia tesselata—a pyriform sponge, Middle Devonian, not uncommon near Torquay.

(143) **Ammonoids.** Locality, Whitby.

Two ammonoids cut longitudinally to show the chambered structure of the shell.

(144) **Greywacke.** Locality, Peebles.

This rock shows the effect of pressure and movement on the ribbed and striated surface, termed slicken-sides.

(145) **Shale.** Locality, Stirlingshire.

In this specimen are embedded numerous lamellibranch fossils, chiefly of the gen. *Modiola.*

(146) **Fossil Fish.** Locality, Baden.

This specimen is an example of *Leuciscus oeningensis*, Agassiz, from the Upper Miocene of Oeningen, Baden.

(147) **Encrinites.** Locality, Devonshire.

This rock is chiefly composed of the crystalline joints and parts of encrinites.

Case G

(148) **Fossil Fish.** Locality, Whitby.

A ganoid fish—*Lepidotus*—showing large, strong, enamelled scales for the protection of the body.

(149) **Lias Rock.** Locality, Whitby.

A dark-coloured rock embedding numerous well-marked belemnite fossils.

(150) **Coal.** Locality, Linton.

This specimen shows lepidodendron markings.

(151) **Fossil.** Locality, Isle of Wight.

Probably a sponge surrounded by a deposit of flint. On the upper surface there is a deposit of quartz crystals.

(152) **Bituminous Shale.** Locality, Midlothian.

This specimen shows a polished surface from pressure and crustal movement, termed slicken-sides.

(153) **Nautilus.** Locality, West Linton.

A fossil *Nautilus* found in a limestone quarry, West Linton.

(154) **Fairy Stones.** Locality, Galashiels.

Fairy stones are concretions of various shapes and sizes due to the consolidation of clay by calcareous or ferruginous cement round a centre. They are generally found in alluvial clays.

PART II—MINERALOGY

CHAPTER V

The Native Elements. Case 1

A mineral is an inorganic body occurring in nature, homogeneous and having a definite chemical composition which can be expressed by a chemical formula. Under favourable conditions it assumes a characteristic crystalline form and it possesses other distinguishing physical characters.

Mineralogy is that branch of geology which treats of the properties of mineral species, which teaches how to differentiate and classify them, and which investigates their mode of formation and any alteration which they may have undergone.

Mineralogy is derived from the word mineral + the Greek word *logos* from *legein*, to speak—a speaking or discoursing about minerals.

At present there are some eighty-three elements identified in the materials which form the crust of the earth. Some of these exist naturally as elements and are termed native elements, but the vast majority of them occur in a state of combination and are called chemical compounds. These elements and compounds form the minerals exhibited in Cases 1 to 4, and which we shall have to consider. The names of the elements are represented by symbols, which consist as a rule of the initial letter of the English or Latin name, or of the initial letter followed by the second or other letter. When this symbol is used alone it signifies a single atom of an element.

A chemical compound is represented by a formula which indicates by symbols the elements of which the compound is composed, and it gives the relative number of atoms in a molecule of the compound.

Oxygen, hydrogen, nitrogen, fluorine, and chlorine are elements which are gases in their free state, as are also the rare 'inert gases,' helium, etc. Mercury is a liquid, and all the other elements in ordinary conditions of pressure and temperature are solid.

The above-named gases, together with carbon, boron, silicon,

sulphur, and phosphorus, are classified as non-metallic elements. Antimony, arsenic, and bismuth possess some of the properties of both non-metallic and metallic elements, and are generally described as semi-metallic or metalloids. All the other elements are classified as metallic.

Chemical compounds of which minerals are composed consist as a rule of a combination of one or more non-metallic elements with one or more metallic elements, combined together in definite proportion.

The various exhibits are classified according to their chemical composition as follows :—

Group I.—The Native Elements ; Group II.—The Sulphides ; Group III.—The Haloids ; Group IV.—The Oxides. The next groups are composed of oxygen salts and are subdivided according to the acid which combines with a metal to form the various salts, viz. : Group V.—Carbonates ; Group VI.—Silicates ; Group VII.—Phosphates ; Group VIII.—Sulphates.

Group I.—Native Elements

Carbon—symbol C—from the Latin name *carbo*.

Carbon is here exhibited in two forms, viz. diamond and graphite or plumbago.

Case 1

(1) **Diamond.** Locality, South Africa.

Diamond is derived from the French *diamant*, a corruption of *adamant*, from the Greek *adamas*, unconquerable—in reference to its extreme hardness.

It crystallises in the cubic system and frequently in the octahedral form. The cleavage is good in four directions parallel to the pairs of parallel faces of the octahedron. The sp. gr. is 3·52, and the hardness is 10 in the scale—the hardest of all known substances. It is generally colourless or slightly yellow, though sometimes the colour varies. It has an adamantine lustre, and, owing to its high refractive properties, a faceted diamond displays brilliant flashes of rainbow colours.

Diamonds are greatly valued as gems. Bort is a general name for inferior diamonds which are broken, crushed, and used by lapidaries for cutting and polishing diamonds and other precious stones. This term is also applied to the amorphous form.

In the amorphous form as bort and carbonado, diamond is used extensively by mining engineers for rock drills.

The principal sources of diamonds are South Africa, India, and Brazil. There are other countries in which diamonds are found, but the supply from these countries is not very important. Diamonds occur either in rock as at Kimberley, or in alluvial deposit as on the coast of Namaqualand, South West Africa, and in certain river basins.

(2) **Blue Ground or Kimberlite.** Locality, Kimberley, South Africa.

Blue Ground is named from the *colour of the rock*, and Kimberlite from *Kimberley*. There are two specimens of this diamondiferous rock in which diamonds are found in South Africa. It is the material which fills old volcanic pipes round Kimberley, and is an aggregate of alteration products of various olivine rocks. Chemically it is essentially a hydrated magnesian silicate. In structure it is fragmentary, and it partly represents the original mother-rock of the diamond which has been broken and shattered by volcanic explosions, and which, in an altered form in this pyroclastic breccia, now fills the volcanic vent. The specimens are greyish in colour with a bluish tinge, and on the fractured surface there is a dark-grey colour with a greenish tinge.

(3) **Graphite or Plumbago.** Locality, Ontario.

(4) **Graphite or Plumbago.** Locality, Cumberland.

Graphite—from the Greek *graphe*, writing, +*ite*—in reference to writing pencils which contain it.

Plumbago—from the Latin *plumbum*, lead—sometimes called ' black lead.'

Graphite, like the diamond, is composed simply of the element carbon. As a rule it is imperfectly crystallised in the form of scaly, lamellar, or fibrous masses. Only rarely is it found in hexagonal crystals of small six-sided scales. It is black in colour and opaque, with a sp. gr. of 2·2. There is perfect basal cleavage ; the lustre is metallic ; it feels greasy to the touch, and it marks objects with which it comes in contact. It is one of the softest of minerals. Graphite is much used in making pencils, and inferior qualities are manufactured into grate polish, foundry facings, and crucibles. The purified material is employed as a dry lubricant.

The difference in properties between diamond and graphite is due to the difference in their respective molecular arrangements.

Graphite is widely distributed, but the chief supply comes from Ceylon, Austria, Italy, and Madagascar. It is chiefly associated with pre-Cambrian gneisses, schists, and crystalline limestone, in which it occurs either in the form of flakes, or as lenticular masses, or as veins.

Sulphur—symbol S—from the Latin name *sulphur*. Sulphur crystallises in the orthorhombic system; there is imperfect cleavage and the fracture is conchoidal. The hardness is 2 in the scale, and the sp. gr. is 2. It has a characteristic colour which varies from primrose to orange-yellow. The lustre is resinous. It usually occurs in massive form and is frequently mixed with calcite. It is also found as small crystals lining cavities in volcanic rock and on surfaces where it has been deposited by sublimation.

(5) **Sulphur Crystals.** Locality, New Zealand.
A specimen of sulphur showing crystalline faces, pale yellow in colour with a faint tinge of green.

(6) **Massive Sulphur.** Locality, Australia.
This sample of sulphur is massive in form, orange-yellow in colour, brittle, and easily fractured.

(7) **Massive Sulphur.** Locality, New Zealand.
Massive sulphur, pale yellow in colour.

(8) **Sublimed Sulphur.** Locality, New Zealand.
Sulphur deposited on the surface of tuff, pale yellow in colour, and showing crystalline formation.

(9) **Sulphur.** Locality, New Zealand.
Sulphur deposited among or mixed with calcite.

Sulphur is used in the manufacture of sulphuric acid, paper, rubber, matches, gunpowder, etc.

The chief supply of sulphur comes from Sicily and the United States. In both places it is associated with limestone. Sulphur is also frequently found as a deposit in volcanic areas.

Arsenic—symbol As—from the Greek *arsenikon*. Arsenic crystallises in the rhombohedral system, but crystals are rare. It is generally found in massive form with a mammillated or rounded surface. The fracture is uneven, finely-granular in appearance, and pale steel-grey in colour. It has a metallic lustre which readily tarnishes to a dark grey when exposed to the

atmosphere. In the scale of hardness it is 3·5, and the sp. gr. is 5·7. It is found in metalliferous veins with other ores.

(10) **Arsenic.** Locality, Saxony.

A dark-grey, heavy, compact rock with an uneven tarnished surface. The fracture faces are irregular, granular-looking, and steel-grey in colour, showing a metallic lustre and a trace of iron pyrites.

White arsenic of commerce—arsenic oxide—is employed in the manufacture of certain pigments and in making glass and enamel. It is also used to some extent in medicine. A few insecticides and weed destroyers contain salts of arsenic.

The chief supply of arsenic is from Saxony and the Harz Mountains.

Antimony—symbol Sb, from the Latin name *stibium*. Antimony is derived from the old Latin name *antimonium*—a word of unknown origin.

This element has a tin-white colour and metallic lustre. It crystallises in the rhombohedral system, but it is generally found as granular or lamellar masses. There is perfect cleavage in one direction. In the scale of hardness it is 3, and the sp. gr. is 6·7. It occurs generally in metalliferous veins along with other ores.

(11) **Antimony—Native.** Locality, Lucknow, New South Wales.

(12) **Antimony—Native.** Locality, Lucknow, New South Wales.

Both rocks (11 and 12) are composed of white and grey calcite. On the calcite there are deposited numerous white grains—some flattish, others roundish—of native antimony which have a strong metallic lustre.

Antimony is used in many alloys such as Britannia metal, pewter, type metal, antifriction metal, and also to give brittleness to shrapnel shells. Vinum Antimoniale and Tartar Emetic are medicines which contain antimony. Metalliferous veins containing this element are not plentiful, and the chief supply comes from Sweden, Australia, and Borneo.

Bismuth — symbol Bi—from the German name *bismuth*. Bismuth crystallises in the rhombohedral system, but natural crystals are very rare. It generally occurs in granular masses or dendritic forms in metalliferous veins. Basal and rhombohedral cleavages are perfect. In the scale of hardness it is 2·5, and there is the high sp. gr. 9·8. It very often shows a yellowish tarnish,

but when fresh it is a silvery white with a tinge of red. It has a metallic lustre and is opaque.

(13) **Bismuth.** Locality, New South Wales.

A greyish, granular-looking, compact rock, composed essentially of crystals of quartz and many whitish grains of native bismuth which show a metallic lustre with a faint reddish tinge. Some of the grains have a yellowish tarnish.

Bismuth is an important constituent in many fusible alloys. It is sometimes used in making stereotype plates, and it is employed to some extent in medicine. The chief supply of bismuth comes from Bolivia, Saxony, and Australia, where it is found in metalliferous veins associated with ores of cobalt, silver, and other minerals. In New South Wales it occurs as a deposit near the junction of granite intrusions in shale.

Gold—symbol Au, from the Latin name *aurum.* Gold seldom occurs in crystalline form, and when it does so the crystals belong to the cubic system. It is generally found in grains of various sizes and shapes, and sometimes it is in nugget form. In small grains it frequently occurs disseminated through rocks in metalliferous veins. The colour is a characteristic dullish yellow, and there is a metallic lustre which does not tarnish. The hardness is 2·5 in the scale, and the sp. gr. of pure gold is 19·3. It is malleable, ductile, opaque, and insoluble in hydrochloric or nitric acid, but it is soluble in a mixture of the two—Aqua Regia.

(14) **Gold—Native.** Locality, Glengaber, Megget.

In a small phial there is a number of flattish pieces of gold, gathered from the sands of Glengaber Burn.

(15) **Gold—Native.** Locality, Bendigo.

In a bottle there are grains of gold of various sizes from Bendigo, Australia.

(16) **Gold—Native.** Locality, New Zealand.

In a phial a few small flattish pieces of gold from Dunedin.

(17) **Auriferous Conglomerate.** Locality, Rand, South Africa.

A heavy, solid rock, dark and light-grey in colour, composed essentially of fragments of quartz cemented together by a siliceous material which contains quantities of minute grains of native gold. This rock is known locally as 'banket.'

(18) **Auriferous Quartz.** Locality, New South Wales.

A ferruginous stained quartz rock containing very small grains of gold. The specimen is from Lady Carrington Mine, Australia.

(19) **Auriferous Quartz.** Locality, California.

A white and dark-grey coloured rock which contains grains of gold and pyrites.

(20) **Auriferous Rock.** Locality, Brazil.

A dark-coloured, somewhat iridescent rock composed essentially of copper and iron, and containing numerous small grains of native gold.

(21) **Auriferous Rock.** Locality, Siberia.

A heavy, dark-brown and white rock, composed essentially of quartz and ironstone, in which are deposited many small grains of native gold.

Gold is very widely distributed and occurs in almost all countries. The principal sources of supply are South Africa, Australia, and the United States, where it is found disseminated in rocks—especially quartz—in metalliferous veins, or as alluvial gold in detrital deposits where the gold-bearing rocks have weathered and disintegrated.

Pure gold is very rarely used in the Arts. Gold used for coinage, ornaments, jewellery, etc., is an alloy of gold with copper, or with copper and silver.

Silver—symbol Ag, from the Latin name *argentum*. Silver crystallises in the cubic system, but crystals of this mineral are rare. It is generally found in massive, wiry, or arborescent forms, the result of weathering of various silver-bearing minerals. When fresh it is silvery white, but it tarnishes readily. In the scale of hardness it is 3, and the sp. gr. is 10·5. It is malleable and possesses a metallic lustre. Native silver is generally alloyed with a small percentage of gold or copper.

(22) **Silver Telluride.** Locality, Siberia.

A dark-grey, fine-grained, compact rock with metallic lustre. It is massive in structure, and cleavage is indistinct. Essentially it is composed of telluride of silver or hessite.

(23) * **Native Silver.**

A slaty-grey, heavy rock on which is a pale yellowish-green deposit. Part of this rock is wiry-looking and, when the dark coating of tarnish is scraped off the surface, there is a silvery-white, strong metallic lustre to be seen.

(24) **Argentiferous Claystone.** Locality, New South Wales.

This specimen is a fine-grained, heavy, pale-grey and brownish-coloured rock. It is readily scratched with the finger-nail, and it contains grains of native silver.

(25) **Argentiferous Galena.** Locality, Wanlockhead.

A heavy, lead-grey coloured specimen in massive form. It shows well-marked cleavage, and there is a bright metallic lustre. It can be readily scratched with a knife, and it gives a grey streak. Essentially it is composed of sulphide of lead with a small percentage of silver.

Pure silver, like pure gold, is too soft to be extensively employed in the Arts. As an alloy it is used for coinage, ornaments, jewellery, and silverware of all kinds. As salts of silver it is of primary importance in photography, etc.

The chief supply is from Mexico, United States, and Canada, though a certain amount is also obtained from Germany, Chile, Peru, etc.

Copper—symbol Cu—from the Latin name *cuprum.* Well-formed crystals of copper are rare and belong to the cubic system. It is generally found in thin plates of frond-like or dendritic structure, or as aggregates in veins of copper ore resulting from the decomposition of copper-bearing minerals. When fresh there is a characteristic copper-red colour with metallic lustre, which readily tarnishes into a dark chocolate-brown, or to a greenish colour from the presence of carbonate of copper or malachite. In the scale of hardness it is 2·5, and the sp. gr. is 8·7. It is soluble in nitric acid, and it is malleable.

(26) **Native Copper.** Locality, Portage Lake, U.S.A.

A large, heavy, irregular nodule with some projecting jagged edges. In parts it is brownish-red in colour and shows the characteristic copper-red with metallic lustre; in other parts it is covered with a pale-green coating of malachite—carbonate of copper.

(27) **Native Copper.** Locality, New South Wales.

This specimen is composed of an aggregate of thin plates with irregular jagged edges. It is dark-brown in colour and when the surface is scraped there is the typical copper-red with metallic lustre.

(28) **Native Copper.** Locality, Canada.

A dark-brown specimen, dendritic in form, with jagged edges and uneven surface. When the dark colour or tarnish is scraped off there is a characteristic copper-red colour with metallic lustre.

(29) **Native Copper.** Locality, South America.

A greenish-coloured specimen, irregular on the surface and jagged at the edges. It consists essentially of copper covered with malachite or carbonate of copper.

The uses of copper are manifold. Pure copper is a good conductor of electricity and is extensively used for induction coils, electrical apparatus, cores of telegraph cables, etc. It is also used in electrotyping processes and so forth. As an alloy in bronze and other forms it is of great importance, and the salts of copper are invaluable in the Arts.

Copper is widely distributed, but the chief sources of supply are the United States, Mexico, Australia, and Spain.

Platinum—symbol Pt—from the Spanish *plata*, silver—from its resemblance to silver. It was first brought to Europe from the Spanish Provinces in South America. Crystals of platinum are very rare and belong to the cubic system. It is generally found in irregular or rounded grains, and occasionally as small nuggets. It is malleable and ductile, but there is no cleavage. The colour is pale steel-grey with a metallic lustre. In the scale of hardness it is 4·5, and the sp. gr., which varies with the amount of impurity, is from 16 to 19 ; in pure platinum it is 21. It is soluble in *aqua regia*—hydrochloric acid + nitric acid—and it fuses with difficulty.

(30) **Platinum.** Locality, Norway.

A small phial containing grains and scales of platinum. They are steel-grey in colour with metallic lustre.

Platinum is employed in chemical laboratories in the form of crucibles, wire, etc., in the contact process of the manufacture of sulphuric acid, in the manufacture of nitric acid from ammonia, in the making of sparking plugs and contact points in electrical works, and it is also used in jewellery.

The chief supply is from the Ural Mountains, other countries contributing a comparatively small amount.

CHAPTER VI

The Sulphides. Case 1

In beginning the description of the various compound minerals it will perhaps simplify matters by defining the terms Radical—Acid—Base—Salt.

Radical.—A compound of two or more elements in which their relative valences or bonds are satisfied is said to be saturated. Thus H_2O or H—O—H is a saturated compound. But sometimes one or two bonds are left unsatisfied and the resulting combination is called a radical. Thus O—H or hydroxyl is a common radical which enters into a compound like a simple element and has a valence of one—that is, it is univalent.

Acid.—An acid is a compound of hydrogen (H), or hydroxyl (OH), with a non-metallic element such as chlorine, nitrogen, sulphur, etc., or a radical containing these elements. The hydrogen atoms of an acid may be replaced by metallic atoms which results in the formation of a salt.

Base.—A base (or hydroxide) is a compound formed of a metallic element or radical and the univalent radical hydroxyl (OH)—that is, an oxide of metal with water or, which is the same thing, a hydrated oxide. Thus CaO the oxide of calcium $+ H_2O$ gives $Ca(OH)_2$ or calcium hydroxide.

Salt.—A salt is formed chemically by the action of a base upon an acid or, which is the same thing, by the neutralisation of the acid. Thus calcium hydroxide or hydrate + acid $= Ca(OH)_2 + H_2SO_4 = CaSO_4 + 2H_2O$.

Base $Ca(OH)_2$ + Acid H_2SO_4 = Salt $CaSO_4$ + Water $2H_2O$. Hence a salt may be simply described as formed from an acid by the replacement of the hydrogen atom or atoms by the metallic element or radical. (*Dana's Mineralogy.*)

Group II. The Sulphides

When sulphur combines with a metal it produces a compound called a sulphide. For example, when sulphur combines with lead it forms the sulphide of lead or galena, with the chemical

formula PbS—that is, one atom of sulphur combines with one atom of lead to produce one molecule of sulphide of lead, and these molecules build up the mineral galena. A similar process takes place when sulphur combines with other metals and metalloids, but the atoms which produce the molecules are not always in equal atomic proportions as in lead. This will be noticed from the formulæ which follow.

Arsenic also plays a like part with the heavy metals in the formation of arsenides; and occasionally both sulphur and arsenic or antimony combine chemically with metals to produce Sulpho-Salts—Salts in which sulphur replaces oxygen in the Oxygen Acids.

Sulphides are frequently found in mineral veins or lodes, and various kinds of sulphides usually occur in the same vein.

Arsenic—symbol As—from the Greek *arsenikon*. The sulphur compounds of arsenic as found in nature are two in number, and these differ from each other in chemical formulæ, crystallisation, structure, colour, and other properties.

Realgar—Sulphide of Arsenic—from the Arabic *rahj-al-ghar*, meaning powder of the mine.

The crystals belong to the monoclinic system, but it is generally found in massive form. The hardness is 1·5 in the scale, and the sp. gr. is 3·5. In colour it is red, with a resinous lustre when fresh, but when exposed to the atmosphere it becomes oxidised, and develops a yellowish or ochreous colour and a powdery consistence. This change produces the yellow sulphide of arsenic (orpiment) with the formula As_2S_3, and white arsenious oxide As_2O_3, which is soluble in water and very poisonous.

Case 1

(1) **Realgar.** Formula AsS. Locality, Washington, U.S.A.

This specimen is a yellowish-brown, ochreous-coloured rock with powdery surface and a fine-grained, somewhat brittle matrix in mass. It is undergoing oxidation.

Orpiment—Sulphide of Arsenic—from the Latin *auri pigmentum*, golden paint, of which orpiment is a corruption. Well-developed crystals are rare, and when they do occur they belong to the monoclinic system. Orpiment usually occurs in lamellar masses with good cleavage in one direction. The hardness is 1·5 in the scale, and the sp. gr. is 3·5. In colour it is lemon-yellow

with a pearly lustre, and it is soluble in *aqua regia* and caustic potash.

(2) **Orpiment.** Formula As_2S_3. Locality, U.S.A.

This specimen of orpiment has a well-marked, foliated structure and a deep lemon-yellow colour with pearly lustre. The lamellæ have a fibrous-looking appearance and are easily marked with a knife.

Formerly orpiment was used for making ' King's Yellow,' which is now produced artificially. It is also employed in the dyeing and manufacture of leather.

The chief sources of supply are Silesia, United States, and other places.

The arsenic of commerce is generally obtained as a by-product of the metallurgical treatment of lead and other ores.

Antimony—symbol Sb, from the Latin name *stibium*.

The sulphide of antimony is termed stibnite. It is also known as antimonite and antimony glance. The crystals are orthorhombic and are frequently in the form of long and large prisms, the faces of which are marked by fine striations parallel to their length. Occasionally the massive mineral consists of fibrous or acicular crystals arranged in stellate form, or it may be composed of lamellar masses. There is perfect cleavage in one direction parallel to the prism edge. Stibnite is 2·5 in the scale of hardness, and the sp. gr. is about 4·5. In colour it is lead-grey with a bright metallic lustre and a streak that is greyish-black. On exposure to light the surface gradually becomes dull with a bluish or blackish tarnish.

(3) **Stibnite.** Formula Sb_2S_3. Locality, New Cumnock.

Here is a heavy, compact, lead-grey coloured mineral with a bright metallic lustre. The prismatic faces are striated parallel to the edge of the prism and they are easily marked with a knife. The streak is dark-grey.

(4) **Auriferous Stibnite.** Locality, Armidale, Australia.

This specimen is similar to No. 3, but in addition it contains a small percentage of gold. The darker colour is due to tarnish from exposure to the atmosphere.

Stibnite is the chief source of metallic antimony, and sometimes it is used in the East as a pigment. It occurs frequently in beds or veins in granite and gneiss, and it is often associated in metalliferous deposits with zinc and lead sulphides—sphalerite and galena. The principal sources of supply are the Harz Moun-

tains, Saxony, Hungary, and Japan. It is also found widely distributed in other countries.

Molybdenum—symbol Mo—from the Greek *molybdos*. The chief mineral of molybdenum is molybdenite—the sulphide—which is frequently associated in veins and lodes with iron and copper pyrites.

Molybdenite crystallises in the hexagonal system but is generally found as platy or scaly masses resembling graphite, though sometimes it occurs in massive form. The basal cleavage is perfect. Molybdenite is a soft mineral, being 1 in the scale of hardness, and the sp. gr. is 4·7. The colour is bluish-black with metallic lustre, and the streak is dark with a tinge of green.

(5) **Molybdenite.** Formula MoS_2. Locality, Washington, U.S.A.

A soft lead-grey coloured mineral with metallic lustre, composed of scales or plates which soil the fingers when touched. It gives a dark streak with a faint greenish tinge, and it can be readily marked with the finger-nail. This specimen is embedded in quartz. On the same tray there is a fine sample of molybdenite free from other minerals.

(6) **Molybdenite.** Locality, Kingsgate, Australia.

This specimen is also embedded in quartz, and in every respect it is similar to No. 5.

Molybdenum ores are used in the manufacture of ferro-molybdenum, a steel-hardening alloy. It is used as a hardener in some cobalt-chromium compounds, and it is also used in the manufacture of certain chemical reagents and of filaments for electric lamps.

Molybdenum ores are widely distributed and very often associated with other sulphides in quartz masses and veins. The chief supplies come from the United States, Australia, Canada, etc.

Silver—symbol Ag, from the Latin name *argentum*. There are several compounds of sulphur and silver, and two specimens, viz. pyrargyrite and argentite, are exhibited in the case.

Pyrargyrite—from the Greek *pyr*, fire, +*argyros*, silver—from its fiery or red appearance. This mineral is also called ruby silver, or dark-red silver ore. It is a compound of silver, antimony, and sulphur, or a sulph-antimonite of silver—one of the Sulpho-Salts. The crystals are usually hexagonal prisms terminated by a flat rhombohedron. The colour of the crystals looks greyish-black, but with transmitted light they are a deep ruby red with a metallic adamantine lustre. The streak or

powder is purplish red, the fracture conchoidal, the hardness 2·5, and the sp. gr. 5·8.

(7) **Pyrargyrite.** Formula $3Ag_2S \cdot Sb_2S_3$. Locality, Saxony.

In this specimen there are several irregular masses of pyrargyrite on a calcite deposit. The masses are very dark-coloured with a purplish tinge and a metallic lustre. In a strong light they become reddish or ruby coloured. The streak is purplish red.

Pyrargyrite is widely distributed, but the chief supplies come from the Harz Mountains, Saxony, Bohemia, and other countries.

Argentite—from the Latin *argentum*. This mineral is also known as silver glance. The crystals belong to the cubic system, but it is usually found in massive form or as arborescent growths. In colour it is very dark lead-grey with metallic lustre, and the streak is nearly black and shining. The fracture is uneven, the hardness is 2·5 in the scale, and the sp. gr. is 7·2. It is readily marked with a knife.

(8) **Argentite.** Formula Ag_2S. Locality, Saxony.

An irregular nugget of dark steel-grey colour with metallic lustre. It is a compact, heavy mineral, but comparatively soft. The streak is greyish-black.

(9) **Argentite.** Locality, Norway.

A dark steel-grey mineral similar to No. 8. It is embedded in a deposit of calcite and quartz.

(10) **Argentite.** Locality, Borneo.

This specimen is a little lighter in colour than Nos. 8 and 9, and it contains some pyrites as well as argentite.

Argentite is a valuable ore of silver and is widely distributed in many countries.

Lead—symbol Pb, from the Latin name *plumbum*. The sulphide of lead is termed galena—from the Greek *galene*, meaning tranquillity—in reference to its supposed soothing effects in certain diseases.

The crystals belong to the cubic system or a modification of it. It is usually found in coarse-grained, massive form, though sometimes it is fine-grained. The crystals are characterised by a perfect cubic cleavage—that is, a cleavage parallel to the faces of the cube. In colour it is lead-grey with metallic lustre, and it has a dark lead-grey streak. In the scale of hardness it is 2·5, and the sp. gr. is 7·5. Galena generally contains a small percentage of silver.

(11) **Galena.** Formula PbS. Locality, Leadhills.

A compact, heavy, dark-grey specimen with bright metallic lustre, which shows well-marked cleavage planes. It is comparatively soft and can be readily marked with a knife.

(12) **Argentiferous Galena.** Locality, Australia.

This specimen is similar to No. 11, but the cleavage planes are not so pronounced. It contains a small percentage of silver.

(13) **Galena.** Locality, Leadhills.

Two small specimens of galena on quartz.

(14) **Galena.** Locality, Derbyshire.

This specimen shows galena crystals in dendritic form.

(15) **Galena.** Locality, Leadhills.

An example of laminated structure in galena.

(16) **Galena.** Locality, Leadhills.

A specimen of galena where the chief characters have been changed by percolating water.

Galena usually occurs in metalliferous veins and is frequently associated with other minerals. It is widely distributed and it is mined in many places, but the chief sources of supply are the United States, Spain, Australia, Mexico, etc. It is the most important ore of lead, and often valuable on account of the silver it contains.

Lead is chiefly used in the form of sheets and pipes, and it is an alloy in pewter, type-metal, soft solder, etc. It is also used in the manufacture of shot.

Zinc -symbol Zn—from the German name *Zink*. Sphalerite, or zinc sulphide or zinc blende, is the most important of the zinc-bearing minerals. Sphalerite is derived from the Greek *sphaleros*, meaning delusive or treacherous ; and blende from the German *blende* (*blind*, meaning deceiving). In both cases the derivation is in reference to the difficulty in distinguishing this mineral from galena. Among miners it is usually termed Black Jack.

Sphalerite crystallises in the tetrahedral division of the cubic system, and has perfect cleavage in several directions. In colour it varies from pale to jet black, but it is usually dark in colour with a characteristic resinous-adamantine lustre. The streak or powder is dark-brown. It is generally found in coarse-grained massive form in veins often associated with galena and other minerals. The hardness is 3·5 in the scale, and the sp. gr. is 4.

(17) **Sphalerite or Zinc Blende.** Formula ZnS. Locality, Leadhills.

This specimen of zinc sulphide shows beautifully marked crystals, blackish in colour, with a resinous-adamantine lustre. The cleavage planes are distinct and the streak is dark brown. The white crystalline deposit on the black crystals is quartz.

(18) **Zinc Blende.** Locality, Australia.

This specimen is in massive form and shows a resinous-adamantine lustre.

(19) **Sphalerite or Zinc Blende.** Locality, Cumberland.

This mineral shows the foliated or plate-like structure sometimes found in sphalerite.

(20) **Sphalerite.** Locality, Cumberland.

In this specimen there are well-marked, very dark, resinous-looking crystals, on which are deposited a few white crystals of quartz.

Zinc is widely distributed, and the chief sources of supply are the United States, Germany, Spain, and other places.

The uses of zinc are manifold, as in the manufacture of brass, German silver, antifriction metal, white metal, etc. It is also used for desilverising lead and as a reducing agent.

Mercury—symbol Hg, from the Latin name *Hydrargyrum.* The sulphide of mercury is called cinnabar. Cinnabar is derived from the Greek *kinnabari*, meaning vermilion, as used by Theophrastus in reference to the red colour of the mineral. This is the only ore of mercury or quicksilver. The crystals of cinnabar are not very common and they belong to the rhombohedral system. Cleavage is perfect and parallel to the prismatic faces of the crystal. Fracture is uneven, and the colour is red with a scarlet streak. This mineral is generally met with in massive form when the colour is often a dullish red. The hardness is 2·5 in the scale, and the sp. gr. is 8.

(21) * **Cinnabar.** Formula HgS.

The specimen exhibited here is massive in form, irregular in outline, brittle, and uneven in fracture. In colour it is dullish red, and a few specks of mercury can be seen on part of the red surface.

The distribution of cinnabar is varied and the principal ore veins are found in Spain, California, and some other countries.

Mercury is much used in extracting gold from its ores. It is

also used in the manufacture of scientific instruments, such as barometers, thermometers, etc.

Copper—symbol Cu—from the Latin name *cuprum*. The mineral chalcocite is the sulphide of copper. Chalcocite is derived from the Greek *chalkos*, meaning copper, + *ite*. It is also called copper glance.

The crystalline form belongs to the orthorhombic system. The cleavage is indistinct and the fracture is conchoidal. In colour it is dark lead-grey, which tarnishes dull with a greenish or bluish tinge. The lustre is metallic and the streak is dark grey. The hardness is 2·5 in the scale, and the sp. gr. is 5·5.

(22) **Chalcocite.** Formula Cu_2S. Locality, Australia.

On the tray there are several pieces of this mineral. It is in mass form, irregular in outline with an uneven cleavage, and compact in structure. In colour it is dark grey with metallic lustre, and throughout the mass there are reddish-brown powdery-looking deposits resulting from oxidation.

(23) **Chalcocite.** Locality, Cornwall.

This is a solid, heavy, dark-grey specimen with a somewhat dull metallic lustre. The streak is dark grey, and a fresh fracture gives a shining surface.

Chalcocite is widely distributed. It is a secondary product and is usually found in copper veins.

Cornwall, Saxony, Norway, etc., are sources of this mineral. It is useful as an ore of copper.

(24) **Pyrrhotite.** Formula approximately Fe_nS_{n+1}. Locality, New South Wales.

Pyrrhotite is also known as magnetic pyrites. The name is derived from the Greek *pyrrhotes*, reddish, in allusion to its colour.

Crystals of this mineral are rare; it usually occurs in massive form. The fracture is uneven, lustre metallic, colour between bronze-yellow and copper-red, and the streak is greyish-black. The hardness is 4 and the specific gravity 4·6.

The specimen on the tray is a heavy compact mineral, pale-bronze in colour, with a copper-red tinge on the fractured surface. In the matrix are several yellow-coloured deposits of chalcopyrites (*see* p. 91), and on the surface is a small deposit of grey quartz.

(25) **Bornite.** Formula Cu_3FeS_3. Locality, Australia.

Named after the mineralogist *von Born.* Also called variegated copper ore.

The crystals of bornite belong to the cubic system, but it is generally found in massive form. The fracture is brittle and uneven. The hardness is 3·5 in the scale, and the sp. gr. is 5. In colour it is usually reddish-brown on a fresh surface, but this readily tarnishes into a bluish iridescent hue. The streak is greyish-black.

The specimen in the case is a heavy compact mineral in massive form. It is irregular in outline, with a dark bluish iridescent sheen. Embedded in the mass there are white crystals of calcite which show well-marked cleavage planes.

(26) **Bornite.** Locality, Logan Lea.

This specimen is from a boulder at Logan Lea, and shows deposits of dark-coloured bornite in the matrix of the boulder.

Bornite occurs both as a primary and a secondary mineral. As a primary it is found in igneous rocks, and as a secondary it is associated with other copper ores in copper sulphide veins.

It is valuable as an ore of copper.

(27)* **Pentlandite.** Formula (Fe, Ni)S. Named after *Mr Pentland.*

This mineral consists of iron, nickel, and sulphur, and is usually in massive form. It has octahedral cleavage, and there is a brittle and uneven fracture. The colour is a bronze-yellow with metallic lustre, which tarnishes to a dull tone on exposure to light. The hardness is 3·5 in the scale, the sp. gr. is 5, and the streak is bronze-brown.

The specimen in the case is massive in structure. It is irregular in form and dull greyish in colour, with metallic lustre. The streak is grey and the fresh surface gives a clear metallic lustre.

The chief sources of this mineral are Norway, Canada, etc., but it is not of great value.

Cadmium—symbol Cd—from the Greek *Cadmeia.* The sulphide of cadmium is known as greenockite, named after *Lord Greenock,* who discovered it.

This is a rare mineral, occurring in hemimorphic, hexagonal crystals of a yellowish-orange colour, with resinous lustre. There is cleavage in one direction. The fracture is brittle and conchoidal. The hardness is 3·5, and the sp. gr. is 5.

(28) **Greenockite.** Formula CdS. Locality, Bishopton.

This specimen is a yellowish crystal attached to the cork of the small phial in which it is placed.

Greenockite is found in Scotland, Bohemia, and other places. It is not of much value commercially, as most of the cadmium of commerce is produced as a by-product in the smelting of zinc blende and other zinc ores.

Cadmium amalgam with tungsten powder is used in making the filaments of tungsten lamps, and cadmium along with bismuth, lead, and tin is employed in the manufacture of fusible alloys.

Chalcopyrites or Copper Pyrites. Greek *chalkos* +Pyrites (p. 16).

Chalcopyrites is a sulphide of copper and iron. It is the most abundant and the most important copper ore. The crystals belong to the tetragonal system, but this mineral is usually found in compact masses or as scattered grains. The colour is a brass-yellow, but a darker shade than iron pyrites, and it is frequently tarnished and iridescent. The fracture is brittle and uneven, the streak is greenish-black, and the lustre is metallic. The hardness is 4 in the scale—softer than iron pyrites—and the sp. gr. is 4·2.

(29) **Chalcopyrites.** Formula $Cu_2S.Fe_2S_3$. Locality, Leadhills.

A beautiful specimen of copper pyrites deposited on the surface of a large irregular mass of calcite. Many of the crystals show tetragonal form, and in other parts the structure is massive. The colour is a deep brass-yellow, and there is a slight tarnish over some of the crystals.

(30) **Chalcopyrites.** Locality, Leadhills.

Another beautiful specimen of copper pyrites. In this case the crystals are more tarnished, deeper in colour, and more iridescent than in No. 29. The pale-brass coloured crystals associated with the darker copper pyrites crystals are crystals of iron pyrites, the dark lead-grey shining crystals are crystals of galena, and the white crystalline deposit is calcite.

(31) **Chalcopyrites.** Locality, Sweden.

A compact mass of copper pyrites with deep brass-yellow colour which is becoming tarnished. The surface of the mass looks somewhat granular.

(32) **Chalcopyrites.** Locality, Derbyshire.

This specimen consists of crystals of copper pyrites embedded in calcite. Some of the crystals are tarnished and beautifully iridescent.

(33) **Chalcopyrites.** Locality, Wanlockhead.

A rough, irregular, massive specimen, tarnished into a somewhat bronze colour. It also contains some green-coloured malachite and some quartz crystals.

(34) **Chalcopyrites.** Locality, Australia.

Another compact specimen of copper pyrites with a clear brass-yellow colour and metallic lustre. The white crystalline deposit is calcite.

Chalcopyrites occurs widely disseminated in metallic veins, often associated with other minerals. It is mined in Cornwall, Sweden, Harz Mountains, Spain, and other places. It is valuable commercially as an ore of copper.

Iron—symbol Fe—from the Latin name *ferrum*. The sulphide of iron is known as pyrite or pyrites. Derivation, *see* p. 16.

The crystals of pyrites belong to the cubic system. There is no distinct cleavage, and whether in crystalline or compact masses it has a pale brass-yellow colour with a bright metallic lustre. The streak is greenish-black, and the fracture is brittle and irregular. In hardness it is 6 in the scale, and the sp. gr. is 5. With difficulty it can be scratched with a knife.

(35) **Iron Pyrites.** Formula FeS_2. Locality, Leadhills.

A fine specimen of pyrites in massive form. The surface is clean and gives a pale yellow colour with bright metallic lustre. It is embedded in a mass of crystalline calcite.

(36) **Iron Pyrites.** Locality not known.

A fine-grained, massive form of iron pyrites, with pale yellow colour and bright metallic lustre.

(37) **Iron Pyrites.** Locality, Cumberland.

A large, rounded nodule of iron pyrites, showing a brass-yellow colour, metallic lustre, and a radiating structure. The white mass on the surface of the nodule is calcite.

(38) **Iron Pyrites.** Locality, Leadhills.

Part of a large crystal of iron pyrites showing typical pale brass-yellow colour and metallic lustre.

(39) **Iron Pyrites.** Locality, Fifeshire.

This specimen shows well-marked crystals of the cubic system. They have the usual yellow colour and metallic lustre. The crystalline mass in which they are embedded consists of calcite and quartz.

(40) **Pyrites Ore.** Locality, Algeria.

On the tray there are two nodules of pyrites ore from Algeria. They are a darkish-grey colour, and the surfaces look granular. The granules have the peculiar colour and metallic lustre of iron pyrites.

(41) **Iron Pyrites.** Locality, Portland.

Another specimen of iron pyrites in massive form showing a somewhat foliated structure.

(42) **Marcasite.** Formula FeS_2. Locality, Cumberland.

This is a sulphide of iron with the same chemical composition as pyrites, but it crystallises in the orthorhombic system and not in the cubic as pyrites does. It is an example of dimorphism—the two have the same chemical composition, but they crystallise in different systems. In many other respects marcasite resembles pyrites.

The specimens on the tray are two roundish nodules—marcasite is generally found in nodules—showing well-marked internal radiating structure. There is the peculiar yellow colour—somewhat tarnished in this case—and the metallic lustre.

Pyrites is one of the most widely distributed of minerals. It is found not only embedded in all kinds of rocks, but also abundantly in metalliferous veins associated with other minerals. Important commercial deposits are worked in Spain, Norway, Germany, and other countries.

Sometimes pyrites is valued for the copper and gold it contains, but it is chiefly mined for the manufacture of sulphuric acid. The uses of iron are too well known to require description here.

Arsenopyrites or *Mispickel.* Locality, Australia.

Arsenopyrites is derived from the Greek *arsenikon*, +*Pyrites*, see above (p. 16). Mispickel is an old German term of doubtful origin.

The crystals are orthorhombic, but sometimes of an elongated prismatic form. It is usually found in massive aggregates, columnar or granular in structure. The fracture is brittle and uneven. In colour it is tin-white to steel-grey with metallic lustre. The streak is greyish-black. On exposure to the atmosphere it usually shows a bluish or blackish tarnish. In the scale of hardness it is 6 and can with difficulty be scratched with a knife. The sp. gr. is 6.

(43) **Arsenopyrites.** Formula FeAsS. Locality, Australia.

This specimen of mispickel is in massive form. It is a compact,

heavy mineral, mottled grey in colour, and there is a faint purplish tinge over the surface.

The atomic proportions in this mineral are equal. It is a sulph-arsenide of iron.

(44) **Arsenopyrites.** Locality not known.

On this tray there are two irregular, heavy, compact masses showing tarnished surfaces, purplish blue in colour, with an iridescent sheen.

Arsenopyrites occurs frequently in veins associated with galena, zinc blende, and other minerals. It is of hydrothermal origin and is valuable as an ore of arsenic. It is widely distributed, and the chief sources of supply are Saxony, Sweden, Australia, and other countries.

Cobalt—symbol Co—from the German name *kobalt.* Kobalt is said to be the same as Kobold, a nature spirit or goblin. Kobolds were supposed to inhabit mines and other underground places, and the name was transferred to Kobalt in reference to the trouble this mineral gave the miners (*Cent. Dict.*).

Cobaltite or cobalt-glance is the sulphide of cobalt. It contains cobalt, arsenic, and sulphur in equal atomic proportions, and is therefore a sulph-arsenide of cobalt. The crystals belong to the cubic system and resemble pyrites in form. The fracture is brittle and uneven. The colour is white to steel-grey, and sometimes there is a reddish or violet tinge. The lustre is metallic. In the scale of hardness it is 5·5, and the sp. gr. is 6·2.

(45) **Cobaltite.** Formula CoAsS. Locality, Canada.

A compact, heavy, massive specimen. The fresh fracture is greyish in colour with metallic lustre, but the greater part of the surface has a dark-grey colour due to tarnish from exposure to light.

(46) **Cobaltite.** Locality, Canada.

A granular-looking mineral. The granules show metallic lustre, and the whole surface has a dark purplish-blue colour.

(47) **Smaltite.** Formula $CoAs_2$. Locality, Canada.

From the Italian *smalto,* enamel.

Smaltite is the arsenide of cobalt. Crystals are cubic and rare. It is generally met with in granular and compact masses. In colour it is steel-grey with metallic lustre. The fracture is granular

and uneven, and the streak is dark-grey. In the scale of hardness it is 5, and the sp. gr. is 6·4.

The specimen in the case consists of several small pieces of smaltite in a glass phial. They are deeply tarnished and are of a dark bluish-grey colour.

The most important source of cobalt is the cobalt district in Ontario, where there is abundance of cobaltite and smaltite associated with ores of silver. Cobalt is now produced as a by-product of silver mining in Canada. It is also found in various other places.

Cobalt is employed in the manufacture of steel and other alloys. It is also used for pigments.

Smaltite like cobaltite usually occurs in veins along with ores of silver and copper. It is found in Ontario, Saxony, Bohemia, Cornwall, and other places. It is valued as an ore of cobalt for the preparation of smalt or cobalt blue, which is used as a pigment and for colouring glass and porcelain.

Nickel—symbol Ni—from the Swedish name *Nickel,* an abbreviation of Kopparnickel used by Cronstedt, who discovered nickel in 1756. It is similar to the German *kupfernickel,* which means false copper.

Niccolite is the arsenide of nickel. The crystals are hexagonal, but the mineral is usually found in massive form. The fracture is brittle and irregular. In colour it is somewhat coppery with metallic lustre. The streak is brownish-black, the hardness is 5·5 in the scale, and the sp. gr. is 7·5.

(48) **Niccolite.** Formula NiAs. Locality, Saxony.

From the Latin name *Niccolum.*

The specimen is a heavy, compact, irregular nodule with a tarnished, somewhat coppery-looking colour and with a greenish tinge in places.

Niccolite is frequently found in veins associated with ores of cobalt, silver, and copper. The chief sources of supply are Germany, Canada, Argentina, etc. This mineral is sometimes valued for the extraction of nickel and also as a source of arsenic. Nickel is used chiefly in the form of alloys, as in nickel steels, etc.

(49) * **Tetrahedrite.** Formula $4Cu_2S . Sb_2S_3$.

So named from its *crystalline form*—tetrahedral.

This is a sulph-antimonite of copper, and is also known as grey copper. The crystals belong to the tetrahedral division of the

cubic system. It is also found in massive form. The fracture is brittle and uneven. In colour it varies from steel-grey to iron-black and there is a marked metallic lustre. The streak is dark brown, the hardness is 3·5, and the sp. gr. is 5.

The specimen in the case is a good sample of crystals of tetrahedrite on a quartz base. They show the tendency to tetrahedral form, and are greyish-black in colour with a metallic lustre.

CHAPTER VII

Group III.—The Haloids. Case 1

Haloids—from the Greek *hals*, sea-salt, + *eidos*, form—like sea-salt.

This term is applied to the elements fluorine, chlorine, bromine, and iodine on account of the resemblance of certain of their compounds, especially those with sodium, to sea-salt.

Halite—from the Greek *hals*, sea-salt. Known as common or rock salt.

The crystals are generally in cubes and sometimes distorted. Halite also occurs in massive and granular forms. Cleavage is perfect and parallel to the cube faces. The fracture is brittle and conchoidal, and the lustre is vitreous. When pure it is colourless or white, but when it contains impurities the colour varies much. The hardness is 2·5 in the scale, and the sp. gr. is 2·4. It is soluble in water, and the taste is saline.

Case 1

(1) * **Halite.** Formula NaCl.

On the tray are two specimens of halite. The one is a flat, irregular, crystalline mass. The surface to a large extent is covered more or less with sand and mud. In colour the clean portion of the mass is pale-brown and the streak is whitish. It is easily scratched with a knife, and it has a peculiar saline taste. The other specimen is a clean, pale-brown, crystalline mass with properties similar to those already described. The chief sources of halite are deposits formed by the evaporation of sea water in land-barred gulfs, or salt water in inland lakes. Beds of rock salt have been laid down in this manner in various geological periods. The uses of salt are well known and need not be described here.

Fluorite or Fluor-spar—from the Latin *fluere*, to flow—in reference to its use as a flux in the smelting of ores.

The crystals belong to the cubic system, and very frequently

they are twinned so that corners of one cube project from the faces of another cube. There is perfect cleavage along the four planes parallel to the faces of the octahedron. The range in colour is extensive, and the dark purplish-blue variety is known as ' Blue John ' in Derbyshire. Some fluor-spar crystals show different colours in transmitted and reflected light. The lustre is vitreous, the fracture brittle and conchoidal, the hardness is 4 in the scale, and the sp. gr. is 3·2. The crystals can be scratched with a knife, and they are decomposed by warm sulphuric acid.

(2) **Fluorite.** Formula CaF_2. Locality, Derbyshire.

A chemical combination of lime and fluorine. A massive form of fluorite showing cleavage planes and edges of crystals. It has a pale violet colour, a slight saline taste, and it can be scratched with a knife. There are a few clear, glassy-looking grains of quartz on the surface.

(3) **Fluorite.** Locality, Durham.

This is a specimen of fluor-spar with twin crystals where the angles of some crystals project from the surfaces of the other crystals. It is pale-violet in colour with a purplish tinge. On the surface there are numerous clear, glassy-looking crystals of quartz.

(4) **Fluorite.** Locality, Durham.

Another example of twin crystals of fluorite in which the angles of some crystals project from the surfaces of others. The colour is pale-violet with a purplish tinge.

(5) **Fluorite.** Locality, Derby.

The crystals in this specimen are beautifully developed and show twinning. In colour it is pale-grey or water colour.

(6) **Fluorite.** Locality, Derbyshire.

A nugget in massive form with a very pale-violet colour.

(7) **Fluorite.** Locality, Durham.

Part of a roundish mass from a drusy cavity showing two deposits. The central one is pale-violet in colour and the outer one is dark blue.

(8) **Fluorite**—variegated. Locality, Derby.

A large solid mass with polished surface showing a variety of colours.

(9) **Fluorite**—variegated. Locality, Corsica.

Another large, irregular, crystalline mass showing various colours.

(10) **Fluorite.** Locality, Durham.

The crystals in this specimen are well developed, and the surfaces of many of them are covered with a black crystalline deposit of cassiterite or tin, which has a strong metallic lustre.

(11) **Fluorite.** Locality, Banff.

A sample of fluor-spar with a pale-green colour.

Fluorite is widely disseminated and is chiefly found in veins traversing limestone and other rocks. It is usually associated with galena, zinc, and other minerals. In England it occurs plentifully in Durham and Derbyshire. It is also produced in quantity in the United States, France, and Germany. This mineral is largely used as a flux for metallurgical purposes, especially in the manufacture of iron, steel, lead, and aluminium. It is also employed in the manufacture of opalescent glass and for making special lenses, etc.

Cryolite—from the Greek *kryos*, frost or ice, +*lithos*, a stone —ice stone—in reference to its icy appearance.

The crystals belong to the monoclinic system, but it is usually found in massive form. The cleavage is good and yields approximately cube-shaped fragments. It is white to brownish in colour and it has a vitreous lustre. The hardness is 2·5 in the scale, and the sp. gr. is 3. It is decomposed by sulphuric acid.

(12) **Cryolite.** Formula Na_3AlF_6. Locality, Greenland.

The fluoride of sodium and aluminium. A large, white, irregular, heavy mass, compact in structure. It shows ill-defined traces of crystals, it can be scratched with a knife, and it does not effervesce with hydrochloric acid. The fracture is brittle and uneven.

(13) **Cryolite.** Locality, Greenland.

Another specimen of cryolite, brownish in colour and showing prismatic structure.

Formerly cryolite was much valued as a source of aluminium, but it has been replaced by bauxite. It is still used in conjunction with bauxite as a flux in the production of aluminium. It is also employed in the manufacture of enamels for ironware, opaline glass, etc. The only place where this mineral is found in quantity is on the coast of Greenland.

Atacamite—so named from the *Atacama Desert*, in Chile, where crystals of this mineral are found.

This is a somewhat rare mineral and is composed of the

chloride of copper+the hydroxide of copper. The crystals form rhombic prisms with pyramidal ends. It also occurs in massive fibrous and granular forms. Cleavage is good and the fracture is brittle and conchoidal. In colour it varies from pale to dark green with a clear resinous lustre. The hardness is 3·5 in the scale, the sp. gr. is 3·7, and it is soluble in acids.

(14) **Atacamite.** Formula $CuCl_2.3Cu(OH)_2$. Locality, Italy.

This specimen is green in colour and very irregular in outline. It also contains crystals of sodalite and nepheline. The whole deposit is on a dolerite rock. The mineral was originally found in Atacama, Chile. It also occurs in Bolivia, Australia, and other places.

Before the days of blotting paper, powdered atacamite was used as ' writing sand ' for sprinkling over manuscript to dry the ink.

Embolite—from the Greek *embole*, a throwing in or insertion —in reference to this mineral being intermediate between cerargyrite and bromyrite.

Embolite consists chiefly of the chloride of silver and the bromide of silver. It is usually found in massive form. In colour it varies from a greyish to a yellowish-green.

(15) * **Embolite.** Formula Ag(Br, Cl).

There are two specimens on the tray, both massive in form. The colour is grey with a very faint tinge of green. The surfaces are smooth and show cleavage planes. There is no reaction with hydrochloric acid and the surface can be marked with a knife.

This mineral is abundant in Chile, Mexico, and other places, but it is not important from an economic point of view.

Cerargyrite—from the Greek *keras*, horn, +*argyros*, silver—also known as horn silver.

The crystals are small and belong to the cubic system, but the mineral is usually found in massive form. The colour varies from pale-grey to greenish or bluish. The lustre is resinous and it tarnishes to dark-grey on exposure to light. The hardness is 2 in the scale, and the sp. gr. is 5·5. It has a horny appearance and can be cut with a knife.

(16) * **Cerargyrite.** Formula AgCl.

The chloride of silver. This specimen is an irregular greyish mass with a somewhat waxy lustre. It can be readily scratched with a knife and the fresh surface shows a resinous lustre.

CHAPTER VIII

Group IV.—The Oxides. Cases 1 and 2

When oxygen combines chemically with another element the compound produced is termed an oxide. Oxygen in the oxides plays a part similar to sulphur in the sulphides. The element silicon combines with oxygen to produce the oxide of silicon, known as silica and having the formula SiO_2, that is 1 atom of silicon combines with 2 atoms of oxygen to produce 1 molecule of oxide of silicon or silica.

Other elements form oxides in a similar manner, but the atomic proportions of different molecules often vary.

Silicon—symbol Si—from the Latin name *silex*, *silicis*, meaning flint.

Silica in the form of quartz is widely distributed. For the description of quartz see ' Rock-forming Minerals,' Part I.

In ordinary circumstances quartz may be recognised by the following characters, viz. :—

(*a*) The appearance. A vitreous or glassy-looking mineral.
(*b*) The hardness. 7 in the scale. It cannot be scratched with a knife.
(*c*) The fracture. There are no cleavage planes, the broken surface is uneven and shell-like or conchoidal.
(*d*) Chemical reaction. It does not effervesce with acids.
(*e*) Density. Sp. gr. 2·6. It is not a heavy mineral.
(*f*) Crystals. When crystals are developed they form six-sided prisms which end in six-sided pyramids.

There are two varieties of quartz, viz. :—

(A) Crystalline. This variety includes both crystalline and massive formations of quartz possessing vitreous lustre.
(B) Cryptocrystalline—from the Greek *kruptos*, meaning hidden or secret—in reference to the extremely small crystals which compose the mineral. In this variety are included those forms of compact quartz which are built up of vast numbers

of minute crystalline formations, so crowded together that there has been no development of crystalline faces at their boundaries. As a rule they have a flint-like massive form.

A. CRYSTALLINE QUARTZ

In Crystalline Quartz the colour of the crystals and the arrangement of the crystals vary, so that individual names are sometimes applied to specimens.

Case 1

(1) **Quartz.** Formula SiO_2. Locality, Wanlockhead.

Large, well-formed, whitish crystals of quartz showing six-sided prisms ending in six-sided pyramids. They are developed on a base of massive quartz. Scattered over the surface of the specimen are numerous small crystals of iron pyrites.

(2) **Quartz.** Locality, Wanlockhead.

White quartz crystals showing beautiful six-sided pyramidal ends, developed on a base of crystalline calcite.

(3) **Quartz.** Locality, Fort William, Canada.

A mass of quartz crystals showing six-sided pyramidal ends. They are a light smoky colour, and the edges of the pyramid faces are picked out in dark lines. The colour is probably due to some organic compound (Dana).

(4)* **Quartz.**

Large crystals of clear quartz; embedded in many of the crystals are dark acicular (needle-shaped) crystals of tourmaline.

(5)* **Quartz.**

Quartz in crystalline form; the large crystals contain dark acicular crystals of hornblende.

(6) **Quartz.** Locality, Cairngorm.

On this tray there are three specimens of quartz, viz. two large, dark-coloured, smoky-looking crystals in the native state, and a third dark-coloured crystal which has been cut.

Dark, smoky-coloured quartz is known as Cairngorm from the place name, and when it is nearly black the term Morion is sometimes applied to it.

(7) **Quartz.** Locality, Leadhills.

A large specimen of quartz in massive form with concentric structure. The concentric bands are pale-grey, whitish, and pale-brown in colour.

(8) **Quartz.** Locality, Durham.

A mass of clear quartz showing conchoidal fracture and glassy or vitreous lustre. This clear variety of quartz is known as rock crystal.

(9) **Rose Quartz.** Locality, Brazil.

Quartz in massive form showing a pale-rose colour, hence sometimes called rose quartz.

(10) **Amethyst Quartz.** Locality, Iceland.

There are two specimens on this tray of bluish-violet coloured quartz in massive form. This variety in colour is termed amethyst quartz.

(11) **Citrine Quartz.** Locality, Ceylon.

On this tray there are two samples of brownish-yellow coloured quartz in massive form. This variety is usually termed citrine and sometimes false topaz.

Case 2

(12) **Quartz.** Locality, Nevada, U.S.A.

A mass of rock composed chiefly of large, projecting crystals of quartz, coloured a pale rusty colour from the oxide of iron.

(13) **Quartz.** Locality, Derby.

A rounded mass of chalcedony on the surface of which is deposited quartz in crystalline form. Adhering to the surfaces of the quartz crystals are numerous grains of specular iron.

(14) **Quartz.** Locality, Aberdeenshire.

A somewhat irregular, rounded mass from a rock cavity. The outer band of deposit, which has a pale-pinkish colour, is quartz, and the inner icy-looking deposit is crystalline calcite. A few small grains of specular iron are also present. From the outward configuration and colour a nodule of this kind is sometimes called potato stone.

(15) **Quartz.** Locality, Fifeshire.

This specimen is from a drusy cavity. It is a quartz nodule, roundish in form with concentric structure. The outer band of

deposit is whitish, the middle is violet with a faint purplish tinge, and the inner band is a dark smoky colour with pyramidal ends of quartz crystals projecting on the free surface.

(16) **Quartz.** Locality, Ceylon.

An uncut dark specimen and three cut and polished specimens in the clear, the grey, and the dark varieties of quartz. From the reflection on the convex cut surface of the quartz crystal this variety is sometimes called Cat's Eye.

(17) **Quartz.** Locality, Ceylon.

On this tray are two specimens of clear quartz or rock crystal. The one is uncut and the other is cut and polished.

B. CRYPTOCRYSTALLINE QUARTZ

In the cryptocrystalline type of quartz the minute crystalline formations vary in arrangement and in colour. Chalcedony is the chief variety of cryptocrystalline quartz. The name is derived from *Chalcedon*, a place-name in Asia Minor.

It has a finely fibrous texture, and on the surface it often presents a rounded or mammillated aspect. Common chalcedony varies from a whitish to a creamy colour, with a somewhat waxy lustre and a semitransparent appearance. The rarer varieties of chalcedony vary much in colour, and frequently the arrangement of the differently coloured portions of the mineral gives rise to special names by which the variety of chalcedony is known.

(18) **Chalcedony.** Formula SiO_2. Locality, New England.

A large, irregular mass, the surface of which is somewhat nodular. It is brownish in colour with a waxy-looking lustre, and the fresh-fractured surface is conchoidal and translucent. The colouring is in part due to the oxides of iron. It is hard and cannot be marked with a knife, nor does it effervesce with acids.

(19) **Chalcedony.** Locality, Iceland.

On this tray there are two specimens. The one is part of a roundish nodule from a drusy cavity, showing a solid, compact mass with resinous lustre ; the other is columnar in structure, showing stalactitic formation with resinous lustre. Both specimens are very pale-grey or water colour.

(20) **Chalcedony.** Locality, Ceylon.

A mass of chalcedony with a pale bluish-green tinge, and embedded in the matrix are numerous dendritic or moss-like figures,

dark-green in colour. Dendritic—from the Greek *dendron*, a tree—tree-like.

(21) **Chalcedony—Carnelian.** Locality, Ceylon.

A large pebble of pale bluish-grey and brownish-red colours, cut and polished. The brownish-red chalcedony is termed carnelian. On the same tray there are other two small brownish-red crystals, cut and polished.

Carnelian, derived from the French name *cornaline*, Latin *cornu.*

(22) **Chalcedony—Prase.** Locality, Rum.

Prase—from the Greek *prason*, a leek—from the leek-green colour.

A hard, compact rock, dark in colour and banded in structure. The bands are dull-green and very dark-grey with a faint greenish tinge. This green-coloured chalcedony is termed prase.

(23) **Chalcedony—Plasma.** Locality, South Esk.

Another dark-green, hard, compact rock with resinous lustre and conchoidal fracture. It is feebly translucent. This dark-green coloured chalcedony is termed plasma. Plasma—from the Greek *plasma*, meaning a figure formed or moulded. This stone was formerly largely used for engraved ornaments.

(24) **Chalcedony—Lydian Stone.** Locality not known.

So named from the place-name *Lydia* in Asia Minor.

A rock blackish-grey in colour and compact in structure, composed essentially of chalcedony which is markedly fissured.

(25) **Chalcedony.** Locality not known.

An elongated, somewhat roundish, rough specimen. The outer surface is composed of pale, flint-coloured, platy deposits; the middle layer is a series of thin concentric bands; and the inner layer is composed of quartz crystals showing pyramidal ends. Inside the cavity is a plate-like deposit of calcite.

Agate is a variegated chalcedony, the colours of which are either banded, clouded, or due to visible impurities as in moss agate. The bands are more or less parallel lines of various shades of colour and they may be straight, wavy, or circular. Agate—derived from *Achates*—the name of a river in Sicily whence specimens were brought as stated by Theophrastus (Dana).

(26) **Chalcedony—Agate.** Locality, Perthshire.

A large mass of variegated chalcedony showing both the banded

and the irregular clouded variety. The bands in this case are parallel and wavy, and some of the cloudy parts are dendritic.

(27) **Chalcedony—Agate.** Locality, Perthshire.

On the tray are three specimens of variegated chalcedony or agate. Two have concentric rings and the third is the clouded variety.

(28) **Chalcedony—Agate.** Locality, Perthshire.

Three more specimens of agate in which the bands are wavy and circular.

(29) **Chalcedony—Agate.** Locality, Perthshire.

All three specimens on this tray show bands which are concentric and wavy.

(30) **Chalcedony—Agate.** Locality, Montrose.

A variegated bluish-grey coloured agate. In one section of the specimen the bands are circular, and in another section the structure is clouded.

(31) **Chalcedony—Agate.** Locality, Montrose.

Two specimens of Montrose agate. The larger one is coloured in various shades of blue, concentrically banded in the outer area and clouded in the centre. The smaller specimen is whitish and pale blue in colour—banded and clouded.

(32) **Chalcedony—Agate.** Locality, Montrose.

Here are two specimens of agate. The larger one has a wavy banded structure at the periphery. In the upper segment towards the centre the bands are straight, and in the lower segment the structure is cloudy. The smaller specimen has concentric bands.

(33) **Chalcedony—Agate.** Locality, Montrose.

Three specimens on this tray. The largest one shows concentric bands with a quantity of impure dendritic material ; the next in size has straight parallel bands ; the smallest one shows bands and clouded structure.

(34) **Chalcedony—Agate.** Locality, Forfarshire.

Two specimens on this tray. One is polished and shows concentric banding, the other is unpolished and shows clouded structure.

(35) **Chalcedony—Agate.** Locality, Forfarshire.

An agate showing clouded structure in variegated chalcedony.

(36) **Chalcedony—Agate.** Locality, Forfarshire.

Two specimens with colour varying from pale-blue to brown. The larger one has irregular bands towards the surface and a clouded structure in the centre. The smaller one has a similar structure with the inner bands thin and delicate.

(37) **Chalcedony—Agate.** Locality, Forfarshire.

Two nodular masses cut and polished. The larger one has a variegated brown colour with a reddish tinge in some parts. There are circular bands towards the periphery while the centre is clouded in structure. The smaller one has brighter colours and shows beautiful irregular banding.

(38) **Chalcedony—Agate.** Locality, Forfar.

Two specimens on the tray. One is cut and polished, the other is rough and in the natural state. Both show deposits of jasper in variegated colours.

(39) **Chalcedony—Agate.** Locality, Ayrshire.

On this tray there are three polished slices of agate showing beautiful colours varying from green dendritic or moss-like forms to red deposits of jasper.

(40) **Chalcedony—Agate.** Locality, Ayrshire.

Here are two specimens of clouded agate. One has deposits of reddish and yellowish jasper ; the other has greenish dendritic or moss markings together with a few reddish spots of jasper. They are jasper agates.

(41) **Chalcedony—Agate.** Locality, Ayrshire.

A beautiful variegated specimen showing impurities in greenish moss-like structure.

(42) **Chalcedony—Agate.** Locality, Roxburghshire.

On this tray there are four samples of pale-coloured agate with irregular bands.

(43) **Chalcedony—Agate.** Locality, Roxburghshire.

A dark variegated variety of agate containing reddish bands of jasper—a jasper agate.

(44) **Chalcedony—Agate.** Locality, Aberdeenshire.

The centre of this agate is white, surrounded by reddish-coloured irregular bands. This specimen represents an onyx-eyed agate.

(45) **Chalcedony—Agate.** Locality, Egypt.

An agate with varying shades of brown. The bands are irregular and concentric.

(46) **Chalcedony.** Locality, Ayrshire.

There are two specimens on this tray, each consisting essentially of deposits of jasper, varying in size, embedded in a purer and paler-coloured chalcedony. This variety is sometimes termed Scottish Bloodstone.

Jasper is an impure chalcedony, where the minute crystals or grains are intermixed with clayey material. The colour varies, but it is usually reddish or yellowish, due to the oxides or hydroxides of iron.

Jasper—derived from the Greek name *iaspis.*

(47) **Chalcedony—Jasper.** Locality, Iceland.

Two slices of reddish-coloured jasper with polished surfaces.

(48) **Chalcedony—Jasper.** Locality, Sussex.

A slice of jasper consisting of two bands—the one greenish grey and the other yellowish brown.

(49) **Chalcedony—Jasper.** Locality, Arthur's Seat.

Two slices of mottled jasper cut and polished.

(50) **Chalcedony—Jasper.** Locality, Lake Superior.

A nugget of variegated red jasper polished on one surface.

(51) **Chalcedony—Jasper.** Locality, West Linton.

A mass of red jasper with bands showing different shades of red.

(52) **Chalcedony—Jasper.** Locality, Aberdeenshire.

A lump of jasper with one surface polished showing greyish mottling.

(53) **Chalcedony—Jasper.** Locality, Aberdeenshire.

A mass of jasper with one surface polished showing red mottling.

(54) **Chalcedony—Jasper.** Locality, Aberdeenshire.

A large piece of jasper with one surface polished showing yellowish mottling.

(55) **Chalcedony—Jasper.** Locality, Peeblesshire.

A mass of red jasper pierced by quartz veins.

(56) **Silica.** Locality, Queensland.

Part of a fossil tree in which the wood has been replaced by silica, and part of the silica has been deposited as patches of pale bluish-coloured chalcedony.

(57) **Silica.** Locality, Blenheim, Australia.

A greyish irregular mass. The outer coating is rough and fibrous looking, and scratching with a knife produces a whitish powdery streak. It does not effervesce with acids. The inner structure is pale-grey varying in depth of colour. It has a vitreous lustre and looks translucent. The fracture is conchoidal and it cannot be marked with a knife. It looks opal in character.

(58) **Silica.** Locality, Antigua.

On this tray there are two specimens of fossil wood where the woody tissue has been impregnated and replaced by silica. The surfaces of the specimen are polished and show tree structure.

(59) **Silica—Flint.** Locality, Brighton.

An irregular nodule of dark-coloured flint covered with a whitish, chalky coating. On the fresh surfaces the fracture is conchoidal.

(60) **Silica—Chert.** Locality, Isle of Wight.

Part of a roundish, nodular mass. The colour is grey and the depth of colour varies in the different bands. It does not effervesce with acid, it cannot be marked with a knife, and it shows conchoidal fracture.

Quartz is the commonest of all minerals. The pure clear variety and several of the coloured varieties are employed in the manufacture of jewellery and ornaments of various kinds. Rock crystal is also used for making lenses and other optical requirements. When crushed, or as fine sand, it is suitable as a polishing or an abrading medium. It is employed in the manufacture of porcelain and glass, and it is used in mortar and cement. As quartzite and sandstone it is valuable as building material, etc.

Quartz of various kinds is frequently found in drusy cavities and as veinstone in various rocks. The chief commercial sources are Brazil and Madagascar, where rock crystal occurs in large blocks, but it is found in all other countries.

Opal—from the Greek name *opallios*, an opal.

Opal has the same chemical formula as quartz with the addition of a variable quantity of water. Unlike quartz, however, there is no crystalline structure in opal. It is amorphous and

is simply a dried-up mass of gelatinous or colloid hydrated silica —the silica that is found in solution in water. In colour opal varies from colourless to greyish-black, and in lustre from glassy or vitreous to waxy or pitchy. It can be scratched by quartz, but itself will scratch glass. The sp. gr. is 2. It is soluble in caustic potash and in hydrofluoric acid. The different shades of colour and their arrangement give rise to variety names of opal.

(61) * **Opal.** Formula $SiO_2 + nH_2O$.

An irregular mass, whitish in colour, with a vitreous or somewhat resinous lustre. It is hard and cannot be marked with a knife, but it is not a heavy mineral. The surface shows conchoidal fracture, and with hydrochloric acid it gives no reaction.

(62) * **Opal.**

On this tray there is a slice of common opal with a polished surface showing different shades of white colouring. The lustre is vitreous.

(63) * **Vein Opal.**

A specimen of rock showing a vein of opal with a glassy, somewhat resinous lustre and a conchoidal fracture.

(64) * **Opal—Fiorite or Siliceous Sinter.**

An irregular incrustation mass, whitish in colour with an uneven surface, many of the projections from which are bead-like or globular in conformation. The lustre is vitreous. This is a deposit from siliceous waters of hot springs.

Fiorite—from the place-name *Fiore*, in Tuscany, +*ite.*

(65) * **Rose Opal.**

This specimen of opal has a bright pinkish-red colour, hence the name rose opal—sometimes called fire opal.

(66) * **Dark Opal.**

Another specimen of opal of the dark variety.

(67) * **Jasper Opal.**

In colour this is a brownish-yellow mass with a glassy lustre. Like jasper it contains impurities and its colour is mainly due to iron oxides.

(68) * **Opal.**

A sample of opal showing a somewhat honey colour, with a resinous lustre.

(69)* **Opal.**

This sample is similar to No. 68, but slightly paler in colour.

(70) **Hyalite Opal.** Locality, Frankfurt o/M.

Clear as glass and colourless is this specimen. It forms a crust with a globular surface, deposited on a lava base.

Hyalite—from the Greek *hyalos*, glass, +*ite*, glass-like.

(71) **Precious Opal.** Locality, Queensland.

On this tray are two pieces of opal, whitish in colour, with a tendency to resinous lustre. They show a beautiful display of colours in reflected light.

The opals are chiefly valued as gem stones. The variety termed precious opal exhibits a display of beautiful colours due probably to irregularities and cracks in the structure of the mineral, produced during the consolidation of gelatinous silica.

Opal occurs chiefly in cracks and cavities of igneous rocks and is often found in other media. The chief sources of supply are Hungary, Mexico, Australia, and other places.

Aluminium—symbol Al—from the Latin word *alumen*+*ium*.

The oxide of aluminium is termed alumina. It occurs naturally as corundum, sapphire, ruby, and emery. The crystals of corundum belong to the rhombohedral system and they occur frequently as six-sided prisms or pyramids. There is a wide range in regard to colour. Next to the diamond it is the hardest of all minerals, being 9 in the scale, and the sp. gr. is 4. The fracture is somewhat conchoidal, with a lustre that varies from adamantine to vitreous. It is insoluble in hydrochloric and other acids. From external appearance some of the names indicate varieties of the mineral, but in their essential characters—chemical composition, hardness, sp. gr., crystalline structure, etc.—they are all alike.

The differences in appearance depend mainly on colouring matter and impurities. Corundum when pure is colourless and transparent, but when inorganic colouring matter is present the crystals may assume brilliant colours.

(72) **Corundum—Sapphire.** Formula Al_2O_3. Locality, Ceylon.

On this tray there is a quantity of sapphires in various colours and mostly water-worn, with rounded surfaces and dull appearance. Some of them show vitreous and others resinous lustre.

Corundum—from the Hindu *korund*; sapphire—from the Greek *sappheiros*.

(73) **Corundum—Sapphire.** Locality, Ceylon.

Specimens similar to No. 72, cut and polished. They show different colours including smoky, bluish-violet, water, pale-green, pale-citrine (or lemon), pale-pink, and ruby.

(74) **Corundum—Massive.** Locality, Ceylon.

Two pieces of corundum in massive form, brownish in colour and irregular in outline.

(75) **Corundum—Emery.** Locality, Ceylon.

Corundum sand. Greyish in colour and containing some small black grains of iron oxides.

(76) **Gravel.** Locality, Ceylon.

A sample of gravel from a gem pit in Ceylon where corundum sapphires are found.

(77) **Gravel.** Locality, Australia.

A sample of gravel from a gem pit in Australia. The different varieties of corundum, especially those of brilliant colours, are much valued as gem stones. In the form of sand, corundum or emery is used for polishing and abrasive purposes.

Magnesium—symbol Mg—origin of name doubtful, perhaps derived from *Magnesia*, a district in Thessaly (see p. 119). The oxide of magnesium and aluminium is termed spinel—probably from the Latin *spina*, meaning a thorn—in reference to the shape of the crystals.

The crystals belong to the cubic system and are often found as octahedra. The fracture is conchoidal and brittle, and the cleavage is imperfect. The lustre is vitreous. There is a wide range of colour from red to blue, yellow, etc. The hardness is 8 in the scale, and the sp. gr. is 4.

(78) * **Spinel.** Formula $MgO.Al_2O_3$.

This specimen is a greyish, brittle mass of crystalline calcite containing numerous small greenish-black crystals of spinel.

Spinel is employed chiefly as a precious stone in jewellery. When cut and polished the red variety or ruby spinel very closely resembles the true or corundum ruby. It is found in pebbly form in gem pits in Ceylon, and in limestone formations in Burma, Siam, and other places.

Copper—symbol Cu, from the Latin *cuprum*. The oxide cuprite is also known as red copper ore. The crystals form in

the cubic system and they usually develop as octahedra, but cuprite often occurs in massive and granular formations. The fracture is conchoidal, the hardness is 3·5 in the scale, and the sp. gr. is 6. The lustre is adamantine to submetallic, and the colour is generally red of various shades.

(79) * **Cuprite**—formula Cu_2O—Cuprous Oxide.

A specimen of red copper ore or cuprite in massive form. It is weathered and decomposed in some places, but it still shows the dark reddish colour of copper oxide. It is a compact heavy mineral.

(80) **Cuprite.** Locality, Australia.

A large, compact, heavy sample of cuprite in massive form. It is somewhat banded in structure, and the bands vary in colour from dark reddish-brown to green. The green band is the carbonate of copper or malachite (p. 127).

(81) **Cuprite.** Locality, Australia.

This specimen shows reddish-brown cuprite surrounded by green-coloured malachite.

On the upper surface there are a few thin blue lines of azurite —another carbonate of copper.

Cuprite is valuable as an ore of copper and is generally a mineral of secondary origin. It is widely distributed and occurs in Thuringia, Cornwall, France, and other countries.

Antimony—symbol Sb, from the Latin name *stibium.* The oxide of antimony exhibited in the case is termed cervantite—from *Cervantes*, a district in Spanish Galicia, where the mineral is found, +*ite.*

This mineral generally occurs as acicular crystals or in massive form. It is yellowish-white to greyish in colour and has a sp. gr. of about 5. It is softish in consistence and can be readily marked with a knife.

(82) **Cervantite.** Formula $Sb_2O_3 . Sb_2O_5$. Locality, Australia.

A fawn-coloured, massive specimen with pale-grey streaks. It looks fibrous in structure and can be readily marked with a knife, leaving a pale powdery streak. This is not a very important mineral.

Iron—for the description of iron oxides see 'Rock-forming Minerals,' Part I, pp. 14–16.

(83) **Micaceous Hematite.** Formula Fe_2O_3. Locality, Perthshire.

An irregular, dark-coloured mass, showing a foliated or micaceous structure. It has a softish consistency and a somewhat unctuous feel. The lustre is bright and metallic.

(84) **Specular Hematite.** Locality, Elba.

A specimen composed of iron-black, rod-shaped crystals, showing strong metallic lustre, deposited on a base of red hematite. This variety is called specular iron from the lustre of the crystals.

(85) **Red Hematite.** Locality, New South Wales.

A large mass of red hematite with a smooth, shining surface and reniform or kidney-shaped in outline, hence sometimes called kidney ore. It has a metallic lustre and its streak is brownish-red.

(86) **Red Hematite.** Locality, New South Wales.

A heavy, compact specimen in massive form, varying in colour from brownish-red to brownish-black with metallic lustre.

(87) **Red Ochreous Hematite.** Locality, West Lothian.

A specimen of red hematite, decomposing to a soft reddish and ochre-coloured mass.

(88) **Specular Hematite.** Locality, West Lothian.

Irregular in outline, black in colour with bright metallic lustre, this specimen of specular iron shows laminated and crystalline structure.

(89) **Specular Hematite.** Locality, Lancashire.

This specimen shows black rod-like and plate-like crystals on a base of brownish-red hematite. On the surface there are a few large smoky-coloured crystals of quartz.

(90) **Hematite-Powder.** Locality not known.

In a phial there is a quantity of reddish-brown, ochreous powder of hematite.

(91) **Magnetite.** Formula $FeO.Fe_2O_3$. Locality, New South Wales.

An irregular, heavy, compact mass of magnetic iron ore. The surface is bluish-black, and the fresh-fractured surface is dark-brown, varying in shade.

This is the protoxide+sesquioxide of iron.

(92) **Magnetite.** Locality, U.S.A.

Another irregular, heavy, compact mass, dark steel-grey in colour with a faint purplish tinge and metallic lustre.

(93) **Ilmenite.** Formula $FeO.TiO_2$. Locality, New Zealand.

An irregular water-worn nugget of ilmenite, brownish-black in colour with metallic lustre. On some parts of the surface there is a deposit of mica. Ilmenite contains a percentage of the element titanium, hence this mineral is sometimes called titaniferous iron.

(94) **Ilmenite—Iserine.** Locality, New Zealand.

A phial containing a quantity of granular ilmenite in the form of sand, hence called iron sand and sometimes termed iserine (p. 15).

(95) **Ilmenite.** Locality, Cornwall.

Two small phials each containing a quantity of granular ilmenite in the form of sand. The samples are from Menaccan in Cornwall, hence sometimes termed menaccanite.

(96) **Limonite.** Formula $2Fe_2O_3.3H_2O$. Locality, West Lothian.

A heavy, dark-brown, compact specimen –the hydrous sesquioxide of iron.

(97) **Limonite Pseudomorph.** Locality, Lancashire.

This specimen is a pseudomorph of limonite after pyrites, where the sulphide of iron has been replaced by the hydrated sesquioxide of iron or limonite. The crystalline outlines are well preserved. The colour is a dull-brown.

(98) **Limonite.** Locality, New South Wales.

An irregular shell of clay ironstone, where the iron has decomposed into the hydrated sesquioxide or limonite. It has a greyish to yellowish colour.

(99) **Limonite.** Locality, New South Wales.

A mass of brown hematite, irregular in outline and porous looking in structure, with a dull lustre.

Limonite, from its generally brownish colour, is sometimes termed brown hematite. It is a secondary product and has no crystalline form.

Goethite—named after *Goethe*, the German poet.

This mineral is a hydrated sesquioxide of iron and crystallises in the orthorhombic system. Cleavage is parallel to the length of the crystal. It is generally found in massive form in fibrous and platy aggregates. The hardness is 5·5 in the scale and the sp. gr. is 4·2. In colour it is yellowish to brown, the streak is brownish, and the lustre is dull and sometimes metallic.

(100) **Goethite.** Formula $Fe_2O_3 . H_2O$. Locality, New South Wales.

This specimen is massive in form and consists chiefly of rounded and platy aggregates. In colour it is in part yellowish-red and in part dark-brown, and its aggregate structure gives it a granular appearance.

(101) **Goethite.** Locality, U.S.A.

A heavy, compact, dark-brown mineral, with an irregular, stalactite-looking surface. The ferruginous matrix on which it rests contains white quartz crystals.

Franklinite—from the place-name *Franklin*, New Jersey, where it is found.

The crystals belong to the cubic system and often develop octahedra. It is usually found in massive form and granular structure. The fracture is somewhat conchoidal, the hardness is 6 in the scale, and the sp. gr. is 5·2. In colour it is black or brownish black, the streak is dark-brown, and the lustre is metallic.

(102) **Franklinite.** Formula $(Zn,Fe,Mn)O . (Fe,Mn)_2O_3$. Locality, New Jersey.

This mineral is an oxide of zinc, iron, and manganese. In colour it is a dark brownish-black, somewhat porous-looking mass with an uneven surface, a metallic lustre, and a dark reddish-brown streak. It is brittle in consistency and coarse in structure.

The use of Franklinite is as an ore of zinc, but it is not a very important mineral.

Chromium—symbol Cr—from the Greek *chroma*, colour, +*ium*—in reference to the colours of its compounds. Chromite is the oxide of chromium—from *chrom*, +*ite*.

Chromite crystallises in the cubic system, and generally as octahedra, but it is usually found in massive and granular formations. It is 6 in the scale of hardness, and the sp. gr. is 4·5. The fracture is uneven, the lustre is from metallic to submetallic, and the colour is generally from black to brownish-black. The streak is dark-brown.

(103) **Chromite.** Formula $FeCr_2O_4$. Locality, New South Wales.

A compact, heavy, brownish-black mineral with a somewhat dull metallic lustre and a dark-brown streak.

(104) **Chromite.** Locality, U.S.A.

On this tray are two samples of chromite. Both are greyish-black in colour with a dull metallic lustre, and they look somewhat granular in appearance, yet firm and solid. The streak is brownish-black.

Chromium is valuable as an alloy with iron for making chromium steel, and as an alloy with cobalt and tungsten it produces stellite, which is employed in the manufacture of cutting tools. It is also used in the manufacture of rustless cutlery, and is valued as an ingredient in making bricks for furnace linings.

Chromite is frequently found in ultra-basic igneous rocks. Some of these rocks decompose into serpentine, hence the chromite often associated with that rock. The sources of supply are Rhodesia and New Caledonia, but it is also mined in other countries.

Tin—symbol Sn, from the Latin name *stannum*. Cassiterite is the oxide of tin, also known as tin-stone. It is derived from the Greek name *kassiteros*, tin.

The crystals of cassiterite belong to the tetragonal system, and they are found generally as prisms or pyramids. This mineral also occurs in massive and granular formations. The fracture is somewhat conchoidal and brittle, the hardness is 6·5 in the scale, and the sp. gr. is 7. The lustre is adamantine, the colour as a rule is between brown and black, and it has a dark-brownish streak.

(105) **Cassiterite.** Formula SnO_2. Locality, New South Wales.

A coarse, massive rock with a few well-developed crystals of quartz towards the centre. In colour it varies from dark-brown to white, and is composed chiefly of cassiterite, pyrites, and quartz. It is a sample from a lode containing these minerals.

(106) **Cassiterite.** Locality, Cornwall.

A heavy, massive, granular-looking rock containing numerous small black crystals of cassiterite in a matrix of quartz and iron. The crystals have a bright metallic or adamantine lustre.

(107) **Cassiterite.** Locality, Cornwall.

A sample of black, shining crystals of cassiterite in a greyish-white felspathic matrix.

(108) **Cassiterite.** Locality, Cornwall.

Large black crystals of cassiterite showing adamantine lustre.

(109) **Cassiterite.** Locality, New England.

A sample of water-worn nuggets of cassiterite, sometimes called stream cassiterite.

(110) **Cassiterite.** Locality, New England.

This tray contains a quantity of black-looking sand of cassiterite. It is found in the beds of streams, hence the variety stream cassiterite.

(111) **Cassiterite.** Locality, New South Wales.

A quantity of beautiful ' Tin Copes ' in a phial.

Tin is used in the manufacture of tin-plate, and in alloys such as bronze, pewter, Britannia metal, type metal, etc.

Tin ore is widely distributed, and the chief supplies come from the Malay States, Bolivia, and the Dutch East Indies.

Manganese—symbol Mn—origin of name uncertain.

Braunite is the sesquioxide of manganese + a small percentage of manganese silicate. Braunite—named after *Braun* of Gotha.

The crystals belong to the tetragonal system and occur commonly as octahedra. It is also found in massive form. There is good cleavage, the fracture is uneven, and the colour and streak are brownish-black. The hardness is 6·5 in the scale, and the sp. gr. is 4·8. The lustre is submetallic.

(112) **Braunite.** Formula $3Mn_2O_3 . MnSiO_3$. Locality, Hartbraunstein.

A dark brownish-black, irregular specimen with a metallic lustre. The surface is uneven and looks somewhat porous and granular.

Manganite—from the name *manganese*.

Manganite is the sesquioxide of manganese. The crystals are usually prismatic and striated in the vertical direction. It is also found in columnar and stalactitic formation. The cleavage is good, the fracture is uneven, and the lustre is metallic. The hardness is 4 in the scale, and the sp. gr. is 4·2. In colour it is steel-grey to iron-black, and the streak is dark-brown.

(113) **Manganite.** Formula $Mn_2O_3 . H_2O$. Locality, Australia.

On the tray are two specimens of very dark crystalline rocks consisting essentially of black prismatic crystals of manganite, striated in the long axis, and showing metallic lustre. The streak is brownish-black.

Pyrolusite—from the Greek *pyr*, fire, +*luo*, to wash—in reference to its decolourising property in the manufacture of glass.

Pyrolusite is the oxide (dioxide) of manganese. It is amorphous and occurs in massive, fibrous form. The hardness is 2 in the scale, and the sp. gr. is 4·8. In colour and in streak it is black, and the lustre is dull metallic.

(114) **Pyrolusite.** Formula MnO_2. Locality, New South Wales.

The specimen is a black, irregular, somewhat vesicular-looking mass. It is easily marked with a knife and the streak is black.

(115) **Pyrolusite.** Locality, Lancashire.

This specimen shows pyrolusite deposited in dendritic form, with moss-like figures on a base of felsite.

Psilomelane—from the Greek *psilos*, smooth, +*melas*, black—in reference to its smooth black appearance.

This mineral is the hydrated oxide of manganese. Pure psilomelane is not common and it is generally found as an impure ore of manganese. In structure it is amorphous and occurs in massive formation in reniform and other shapes. The hardness is 6 in the scale, and the sp. gr. is 4·2, but variable. In colour it is black, the streak is brownish-black, and the lustre is dull submetallic. It generally contains impurities.

(116) **Psilomelane.** Formula probably H_4MnO_5, but the formula is doubtful owing to impurities. Locality, New South Wales.

This specimen is the earthy variety of psilomelane, sometimes called wad, and shows banded formation. The central band is brownish-black, and on each side there is a band of yellowish-red, ochreous material. The specimen can be readily scraped with a knife. Among the impurities this specimen contains is a small amount of cobalt.

Manganese is an important alloy of iron as in ferro-manganese, manganese steel, etc. As an oxidising agent it is valuable, and it is also used as a colouring agent in the manufacture of glass and porcelain. The chief sources of supply are India, Russia, and Brazil.

Magnesium—symbol Mg—perhaps after *Magnesia*, in Thessaly; the basic carbonate was called "magnesia alba."

The oxide of magnesium is termed brucite—named after *Bruce* the mineralogist.

The crystals of brucite are rhombohedral in form and generally

tabular. It also occurs in foliated and fibrous massive formations. The hardness is 2·5 in the scale, and the sp. gr. is 2·4. The folia are separable and flexible, and they are waxy to vitreous in lustre. In colour this mineral is usually white to greyish-white.

(117) **Brucite.** Formula $MgO.H_2O$. Locality, Shetland.

A white to pale greyish-white mineral, composed essentially of foliated crystals of brucite which have a pearly lustre on the cleavage surfaces. It can be easily scratched with a knife, and the streak is pale greyish-white. Brucite occurs in the Western Isles, Shetland Isles, and many other places.

This is a secondary mineral and along with other magnesian compounds it is often found in serpentine and limestone. Magnesium is valuable as an illuminant in the form of flare lights, etc.

Titanium—symbol Ti—so called in fanciful allusion to the Titans (*Cent. Dict.*).

Rutile is an oxide of titanium—from the Latin *rutilus*, yellowish-red—in reference to its colour. The crystals are commonly prismatic and striated in the long direction. It is also met with in massive and granular forms. The fracture is uneven and brittle, the hardness is 6·5 in the scale, and the sp. gr. is 4·2. The lustre is metallic.

(118) **Rutile.** Formula TiO_2. Locality, Bohemia.

This sample of rutile is dark-coloured and granular. It consists essentially of grains of rutile and ferriferous rutile. This dark, granular variety is also known as iserine.

Rutile is derived chiefly from vein and dyke rocks, and also from stream and surface deposits resulting from the weathering and disintegration of rutile-bearing rocks. It has a wide distribution.

Titanium is used in making titanium carbide electrodes for arc lamps, and as a compound it is employed in dying leather and wool, and in the manufacture of steel.

CHAPTER IX

Group V.—The Carbonates. Case 3

From the oxides we now pass to another large class of minerals which includes the salts or compounds of the different oxygen acids. An oxygen acid is any acid that contains oxygen, and an oxygen salt may be simply described as the reaction of a base on an oxygen acid, or the neutralisation of the acid (see Chapter VI).

Carbonic acid in chemical combination with a metal produces a carbonate—thus :

$$\left\{\begin{array}{c}\text{Oxygen Acid}\\ | \\ H_2CO_3 \\ | \\ \text{Carbonic Acid}\end{array}\right. + \left\{\begin{array}{c}\text{Metal Base}\\ | \\ Ca(OH)_2 \\ | \\ \text{Calcium Hydroxide}\end{array}\right. = \left\{\begin{array}{c}\text{Oxygen Salt}\\ | \\ CaCO_3 \\ | \\ \text{Carbonate of Lime}\end{array}\right. + \left\{\begin{array}{c}\text{Water}\\ | \\ 2H_2O \\ | \\ \text{Water}\end{array}\right.$$

A salt may be neutral, acid, or basic.

A neutral or normal salt is one in which the acid element is completely neutralised by the basic element. All the hydrogen atoms of the acid have been replaced by metallic atoms or radicals —thus :

Acid (H_2CO_3)+Base ($Ca(OH)_2$)=Neutral ($CaCO_3$)+Water ($2H_2O$)

An acid salt is one in which all the bonds of hydrogen in the acid are not taken up by the basic element—that is, the acid is not completely neutralised. Thus, K_2SO_4 is normal or neutral sulphate of potash, and $HKSO_4$ is the acid sulphate of potash.

A basic salt is one in which the acid part of the compound cannot supply all the bonds of the base—that is, the base is in excess—thus :

Basic Carbonate of Copper ($Cu_2(OH)_2CO_3$)=Neutral Salt ($CuCO_3$) +Base ($Cu(OH)_2$)=Basic Carbonate of Copper.

The carbonates are divided into two distinct isomorphous groups, viz. : (a) *Calcite group*, (b) *Aragonite group*.

The species of the calcite group crystallise in the rhombohedral system and those of the aragonite group in the orthorhombic system.

Calcite—from the Latin name *calx* (Calc-), lime, +*ite*—the carbonate of lime or calcium. Also known as calc spar, one of the commonest of minerals.

The crystals are rhombohedral and vary from tabular to prismatic in form. It is also found in fine and coarse massive formations, from lamellar to granular in structure, and sometimes it assumes stalactitic, nodular, and other forms. It is very varied in structure. Cleavage is perfect in three directions, the fracture is somewhat conchoidal, the hardness is 3 in the scale, and the sp. gr. is 2·7, which varies a little with the amount of impurity. Calcite is colourless when pure, but it is generally tinged with pale shades of grey, green, violet, etc. The streak is white or greyish, and the lustre is vitreous to dull earthy. This mineral can be readily scratched with a knife and it effervesces with hydrochloric acid. There are many varieties of calcite which depend on differences in crystallisation, structural conditions, impurities, and other things.

Case 3

(1) **Calcite.** Formula $CaCO_3$. Locality, Leadhills.

Large prismatic crystals of calcite, whitish in colour and tapering at the ends in various forms. They contain numerous small, black-looking grains of foreign matter.

(2) **Calcite.** Locality, Leadhills.

This specimen contains four different minerals. The central square-looking, dark-grey mass is galena. The white glassy-looking crystals ending in pyramids are quartz. The pale greyish-looking crystals on the anterior surface of the galena are calcite, and the yellowish cream-coloured base is dolomite.

(3) **Calcite.** Locality, Leadhills.

Large crystals of pale greyish-white calcite on a base of zinc blende or sphalerite.

(4) **Calcite.** Locality, Wanlockhead.

Large crystals of calcite containing impurities, which give it a dark, smoky-looking appearance.

(5) **Calcite.** Locality, Wanlockhead.

Another specimen of large calcite crystals containing foreign matter, which gives them a dark, smoky-looking appearance. The crystals are deposited on a base of galena.

(6) **Calcite.** Locality, Wanlockhead.

An aggregate of white calcite crystals showing cleavage and vitreous lustre. The crystals are on a mass of galena.

(7) **Calcite.** Locality, Derby.

A white and brown specimen of massive calcite showing well-marked cleavage. The brown material is hematite.

(8) **Calcite.** Locality, Peeblesshire.

Dullish-white crystals of calcite on a base of greywacke. From the pointed character of the crystals this variety of calcite is sometimes termed dog-tooth spar.

(9) **Calcite.** Locality, Leadhills.

An aggregate of calcite crystals of pale smoky colour. The projecting crystals have blunted ends, hence this variety is sometimes termed nail-head spar.

(10) **Calcite.** Locality, Midlothian.

A whitish aggregate of calcite crystals showing plate-like structure.

(11) **Calcite.** Locality, Staffa.

A pale pinkish-brown aggregate of calcite crystals showing crystalline cleavage.

(12) **Calcite.** Locality, Lanarkshire.

On this tray are two specimens of pale glassy-looking crystals of calcite surrounding black masses of zinc blende or sphalerite.

(13) **Calcite.** Locality not known.

A banded limestone containing impurities in various forms which occasionally look like landscapes, hence sometimes called landscape marble.

(14) **Calcite.** Locality various.

On this tray are six specimens of different varieties of calcite.

(15) **Calcite.** Locality, Cornwall.

A mass of crystalline calcite mottled greyish-white, with a faint brownish tinge in some places.

(16) **Calcite.** Locality, Lanarkshire.

An aggregate of calcite crystals of the variety nail-head spar on a base of hematite.

(17) **Calcite.** Locality, Midlothian.

Crystals of clear calcite on a base of coal.

(18) **Calcite.** Locality, Iceland.

A banded specimen of very fine-grained calcite with a polished surface which shows a pearly lustre, hence sometimes termed pearl spar.

(19) **Calcite.** Locality, Iceland.

Clear calcite crystals showing the cleavage or splitting of calcite into small rhombohedra. This clear variety is known as Iceland spar.

(20) **Calcite.** Locality, Iceland.

Similar to No. 19, but not so clear and transparent.

(21) **Calcite.** Locality, Derby.

A mass of amber-coloured calcite, banded in structure and stalactitic in origin.

(22) **Calcite.** Locality, Jamaica.

A pale-brown, banded mass of calcite of stalagmitic origin.

(23) **Calcite.** Locality, Durham.

A mass of whitish calcite of stalagmitic origin, with an uneven, nodular-looking surface.

(24) **Calcite.** Locality, Palermo.

A piece of polished, mottled, crystalline calcite or marble.

(25) **Calcite.** Locality, Plymouth.

Another piece of polished, mottled, crystalline calcite or marble.

Aragonite—from the place-name *Aragon* in Spain, +*ite*—the carbonate of lime or calcium.

The crystals are orthorhombic and often acicular, terminated by acute domes or pyramids. It also occurs in massive formation of globular, reniform, and stalactitic structure. The cleavage is imperfect, the fracture is uneven and brittle, the hardness is 3·5 in the scale, and the sp. gr. is 2·9. The lustre is vitreous and on fresh surfaces it is somewhat resinous. The colour varies from

white to grey, yellow, green, etc., and the streak is pale-grey or white. It is easily marked with a knife, and it effervesces with hydrochloric acid.

(26) **Aragonite.** Formula $CaCO_3$. Locality, Gibraltar.

A large, irregular, heavy mass of fine-grained aragonite. It is beautifully banded in varying shades of brown. There are no cleavage planes, the fracture is somewhat conchoidal, and the fresh surface has a resinous look. It is stalagmitic in origin.

(27) **Aragonite.** Locality, Gibraltar.

A heavy, solid, compact rock, polished on two surfaces, showing well-marked irregular banding in various shades of brown. There are no cleavage planes, the fracture is somewhat conchoidal, and the fresh surface has a resinous appearance. This is also a sample of stalagmitic origin.

(28) **Aragonite.** Locality, Gibraltar.

A large, heavy, brownish, nodular mass of aragonite. The surface is uneven and shows the projecting ends of the crystals forming the aggregate mass. The crystals are elongated, thin, and pointed. There is no cleavage and the fresh surface is somewhat resinous in lustre.

The uses of lime and marble (p. 53) are well known.

Though calcite is one of the commonest minerals, yet large, transparent, flawless pieces are comparatively rare and are found chiefly in Iceland as Iceland spar. This flawless variety is much valued for making polarising prisms.

Dolomite—named after the French geologist *Dolomieu*—the carbonate of lime and magnesium.

This mineral crystallises in the rhombohedral system, the crystals frequently showing curved faces. Massive granular formations are also frequently met with. The cleavage is perfect and rhombohedral, the hardness is 3·5 in the scale, and the sp. gr. is 2·8. In colour the crystals are white to yellowish, but not transparent. The lustre is vitreous to dull.

(29) **Dolomite.** Formula $CaMgC_2O_6$ or $CaCO_3.MgCO_3$. Locality, Leadhills.

An aggregate of pale cream-coloured crystals of dolomite, non-transparent and vitreous in lustre. On the specimen posteriorly there are numerous glassy-looking crystals of quartz ending in pyramids, and anteriorly there are several large pale-white crystals of calcite.

(30) **Dolomite.** Locality, Leadhills.

On a basis of iron ore are deposited brownish-coloured crystals of dolomite, and on the dolomite there are a few large, pale-white crystals of calcite.

(31) **Dolomite.** Locality, Sunderland.

An irregular nodular mass of fine-grained, compact, greyish-white coloured dolomite.

(32) **Dolomite.** Locality, Wanlockhead.

A nodule composed essentially of crystals of dolomite and copper pyrites.

(33) **Dolomite.** Locality, Derby.

An aggregate of brownish-looking crystals of dolomite, sometimes referred to as ferriferous or brown spar. Dolomite is often calcined and used in the manufacture of bricks for furnace linings. It is also valued for lithographic purposes and as building material. It is widely distributed and occurs abundantly as beds of magnesian limestone.

Magnesite—perhaps after *Magnesia*, in Thessaly (*see* p. 119)—the carbonate of magnesium.

The crystals belong to the rhombohedral system, but the crystalline variety is not common. The cleavage is rhombohedral and perfect. This mineral usually occurs in massive nodular formations, with a compact texture and a porcellanous appearance on fresh surfaces. The hardness is 3·5 in the scale, and the sp. gr. is about 3. In colour it is usually white with a lustre that varies from vitreous to dull.

(34) **Magnesite.** Formula $MgCO_3$. Locality, New South Wales.

An irregular, whitish mass of magnesite. It is fine grained and compact in structure and can be readily marked with a knife, leaving a white streak.

Magnesite is the source of dead-burnt magnesia which is largely used in the basic lining of steel and copper furnaces. It is employed with magnesium chloride as a cement material—oxychloride cement—and as a fire-resisting paint. Also it is used in the manufacture of magnesium bisulphite, required in the production of paper and other chemical compounds.

This mineral is widely and abundantly distributed and the chief sources of supply are Greece, California, Styria, and other places.

Cerussite—from the Latin name *cerussa*, white lead—also known as white lead ore—the carbonate of lead.

The crystals are orthorhombic in system, and sometimes pseudo-hexagonal, due to twinning. It is also frequently found in granular, massive, and compact formations. Cleavage is distinct, the fracture is conchoidal and brittle, the hardness is 3 in the scale, and the sp. gr. is 6·5. The lustre varies from adamantine to resinous, the streak is pale, and the colour varies from white to grey.

(35) **Cerussite.** Formula $PbCO_3$. Locality, Leadhills.

On this tray there are three specimens of cerussite or white lead in crystalline form. The crystals are pale-grey in colour, are readily marked with a knife, and they effervesce with hydrochloric acid.

(36) **Cerussite.** Locality, New South Wales.

A nugget consisting of a deposit of brownish-coloured cerussite, or carbonate of lead, on a mass of argentiferous galena.

Cerussite, when in quantity, is an important ore of lead. It is a secondary mineral and is generally found in the upper oxidised zones of metalliferous veins and in the upper levels of lead mines where carbonated waters come in contact with galena. It is widely distributed and is found in many areas.

Malachite—from the Greek *malache*, meaning mallow—in reference to its green colour; also called green carbonate of copper—a basic carbonate of copper.

Crystals of malachite are rare and when they do occur they belong to the monoclinic system. They are generally slender, acicular prisms grouped in tufts or rosettes. The mineral is usually found in compact masses, often in nodular form. The fracture is sub-conchoidal and brittle, the hardness is 3·5 in the scale, and the sp. gr. is 3·9. In colour it is green of various shades, the lustre is adamantine to vitreous, and the streak is pale-green.

(37) **Malachite.** Formula $Cu_2(OH)_2CO_3$. Locality, Leadhills.

A nodule composed essentially of malachite, which is the green portion, and copper pyrites, the dark metallic-looking portion with the iridescent hue.

(38) **Malachite.** Locality, Russia.

An irregular, greenish-coloured mass of malachite or basic carbonate of copper.

(39) **Malachite.** Locality, Cobar, Australia.

An irregular, greenish deposit of malachite with an uneven surface, on a base of reddish-brown cuprite or oxide of copper.

(40) **Malachite.** Locality, Burra Burra.

A nodule, irregular in outline and greenish in colour, showing a banded variety of malachite—the bands are in various shades of green.

(41) **Malachite.** Locality, Canada.

Another green nodule of malachite, showing on the surface a somewhat botryoidal or grape-like structure. Locally this rock is known as greenstone.

(42) **Malachite.** Locality, Australia.

A deposit of malachite on cuprite, showing long, slender, acicular crystals grouped in rosettes.

(43) **Malachite.** Locality, Leadhills.

A specimen of rock showing a deposit of green malachite on a pale base.

When cut and polished this mineral is used for ornamental purposes, and in quantity it is valued as an ore of copper. Malachite is associated with other ores of copper and is a product of their alteration. It occurs abundantly in the Ural Mountains, Australia, England, and other places.

Chessylite—from the place-name *Chessy* in France—also called azurite, from the *azure-blue* colour.

Chessylite is another basic carbonate of copper. It contains the same elements as malachite, but they are arranged in different proportions.

The crystals belong to the monoclinic system and are usually short and tabular in habit. The fracture is conchoidal, the hardness is 3·5, and the sp. gr. is 3·8. In colour it is azure-blue with a vitreous lustre and a sky-blue streak. Azurite or chessylite tends to lose carbonic acid—CO_2—and to become malachite, hence the green and blue colours so often associated with ores of copper.

(44) **Chessylite.** Formula $2CuCO_3.Cu(OH)_2$. Locality, Leadhills.

A specimen of rock showing a blue deposit of azurite or chessylite on a base of quartz.

(45) **Chessylite.** Locality, Midlothian.

A sample of rock showing a blue deposit of chessylite on a base of calcite.

(46) **Chessylite + Malachite.** Locality, New South Wales.

A banded mass of copper ore. The blue portion is azurite, the green coloured part is malachite, and the brownish portion is cuprite or copper oxide.

(47) **Chessylite + Malachite.** Locality, Australia.

Another banded mass of copper ore. The blue band is chessylite or azurite and the green band is malachite.

(48) **Chessylite.** Locality, Chessy, France.

An irregular nodule of dark blue chessylite or azurite, sometimes termed blue carbonate of copper. There is also a small specimen on this tray, coloured green and dark-red. The green part is malachite and the dark-red part is cuprous oxide, sometimes called ruby copper. The uses and distribution of chessylite are similar to those of malachite.

Siderite—from the Greek *sideros*, iron—also called chalybite—from the Greek *chalyps*, *chalybos*, steel -the carbonate of iron.

The crystals, which frequently have curved faces, belong to the rhombohedral system. It also occurs in massive granular formations. There is rhombohedral cleavage, the hardness is 4 in the scale, and the sp. gr. is 3·8. In colour it is usually yellowish-brown, with a vitreous lustre and a pale whitish streak.

(49) **Siderite or Chalybite.** Formula $FeCO_3$. Locality, Barrier Range, Australia.

A yellowish-brown coloured specimen of chalybite, showing plate-like or tabular structure. The plate-like surfaces have a vitreous or glassy lustre, and on some of them there is a whitish crystalline deposit of calcite. This sample of siderite contains a small percentage of silver.

(50) * **Siderite.**

A heavy, compact, chocolate-coloured specimen of siderite with a metallic lustre on the fresh-fractured surface.

This mineral is valuable as an ore of iron. The crystalline varieties are usually found in metalliferous veins, and the massive and granular varieties in beds in sedimentary rocks. It is widely distributed and is worked in England, Germany, Australia, and other places.

Smithsonite—so named after *Smithson*, the founder of the Smithsonian Institute, U.S.A.—the carbonate of zinc—also known as calamine—from the Low Latin *calamina*.

It crystallises in the rhombohedral system, but it is usually found in massive form, rounded or spherical in outline. The cleavage is rhombohedral, the fracture is uneven, the hardness is 5 in the scale, and the sp. gr. is 4·3. The colour is variable, but it is usually white or grey with a white streak and a vitreous lustre.

(51) * **Smithsonite.** Formula $ZnCO_3$.

This rock shows a white crystalline deposit of carbonate of zinc or smithsonite on a ferriferous base.

Smithsonite is valued as an ore of zinc. It is found in veins and beds associated with lead, zinc, and sometimes with copper ores. Usually it is a secondary product resulting from the action of carbonated waters on zinc sulphide or sphalerite. It is widely distributed and is found in quantity in Siberia, Hungary, and other places.

CHAPTER X

GROUP VI.—THE SILICATES. CASES 3 AND 4

THE next great group of minerals, 'The Silicates'—or the salts produced by the action of silicic acid on metals or bases—contains the largest number of minerals and also the most complex in regard to chemical formulæ.

The several forms of silicic acid, which vary in the proportion of water to silica, combine chemically with metals or bases to produce the different varieties of silicates. They are as follows :—

(1) $H_2O + SiO_2 = H_2SiO_3$, or Meta-Silicic Acid, in which 1 molecule of water combines with 1 molecule of silica.

(2) $2(H_2O) + SiO_2 = H_4SiO_4$, or Ortho-Silicic Acid, in which 2 molecules of water combine with 1 molecule of silica.

(3) $H_2O + 2(SiO_2) = H_2Si_2O_5$, or Disilicic Acid, in which 1 molecule of water combines with 2 molecules of silica.

(4) $2(H_2O) + 3(SiO_2) = H_4Si_3O_8$, or Polysilicic Acid, in which 2 molecules of water combine with 3 molecules of silica.

FELSPAR AND FELSPATHOID GROUPS

For descriptions of felspars and felspathoids see Part I - Petrology—Rock-forming Minerals.

Orthoclase Series

The species of this series belong to the polysilicic group.

CASE 3

(1) **Orthoclase.** Formula $KAlSi_3O_8$. Locality, Aberdeenshire.

On a base of granite this specimen presents large crystals of pale brown-coloured orthoclase, showing cleavage planes. The crystals can be scratched with a knife with difficulty and they do not react to hydrochloric acid. The black shining crystals are biotite.

(2) * **Orthoclase—Sanidine.**

Sometimes termed glassy orthoclase.

Embedded in a matrix of rhyolite there are a couple of large, oblong, pale, somewhat glassy-looking crystals of sanidine. They are more transparent than orthoclase, but in other respects they are similar.

(3) * **Microcline.**

Microcline is similar to orthoclase in chemical formula, but it crystallises in the anorthic or triclinic system.

The sample on the tray is pale green in colour, massive in form, and shows well-marked cleavage surfaces. It does not effervesce with hydrochloric acid and it can be marked with a knife with difficulty.

The green variety of microcline is sometimes termed amazon-stone. The few glassy-looking crystals on the surface are quartz.

(4) * **Microcline.**

Another pale-green crystalline mass of microcline similar to No. 3.

(5) **Orthoclase—Adularia.** Locality, Switzerland.

The crystals in this specimen are clear and transparent. This clear variety of orthoclase is known as adularia—from the place-name *Adula* in the Grisons Alps. On the surface of the specimen there are some fine, radiating, greenish-looking fibres of actinolite.

(6) **Orthoclase—Moonstone.** Locality, Ceylon.

On this tray there are several specimens of fairly pure and clear orthoclase. One is uncut, and the others are cut and polished. From the reflection or opalescence seen on the surface this variety is known as moonstone.

Plagioclase Series (7–12)

(7) **Albite.** Formula $NaAlSi_3O_8$. Locality, Hirschberg.

A heavy, compact, massive rock, composed essentially of (*a*) Albite—the large, white, crystalline mass with an even surface and showing cleavage planes, (*b*) Orthoclase—the small, reddish-brown looking portion on the side of the specimen, showing cleavage planes, (*c*) Quartz—on the surface of the specimen there are a few glassy-looking crystals of quartz.

(8) **Albite.** Locality, Sweden.

Another specimen of albite in massive form showing well-marked cleavage planes.

(9) **Oligoclase.** Locality, Ural Mountains.

One of the albite-anorthite series in which there is more albite than anorthite. The specimen is a heavy, irregular mass of grey crystalline oligoclase. In some places it shows cleavage planes, it can be scratched with difficulty with a knife, and it does not effervesce with hydrochloric acid.

(10) **Oligoclase.** Locality, Sweden.

Another sample of massive oligoclase, whitish in colour and polished on the surface. Sometimes this mineral contains small scaly inclusions of hematite which produce a brilliant red sheen, and on this account it is sometimes known as sunstone.

(11) **Labradorite.** Locality, Norway and Ireland.

On this tray there are two specimens of labradorite with polished surfaces, showing a beautiful display of colours in certain positions, due to the inclusion of vast numbers of microscopic plates of other minerals arranged in parallel order.

The larger of the two specimens is from Norway and the smaller is from Ireland.

(12) **Anorthite.** Formula $CaAl_2Si_2O_8$. Locality, Vesuvius.

This mineral is the basic end of the albite-anorthite series, and is a calcium aluminium silicate. The specimen is an aggregate mass of whitish crystals of anorthite with a few black-looking crystals of pyroxene.

Some of the felspars when cut and polished are used for gemstones, as in the case of moonstone (opalescent orthoclase), amazonstone (green microcline), and sunstone (spangled oligoclase). Labradorite is also valued for ornamental purposes. Moonstone is found chiefly in Ceylon, amazonstone in the United States and the Urals, sunstone in Norway and Canada, and labradorite in Labrador and other places.

(13) **Leucite.** Formula $KAlSi_2O_6$. Locality, Vesuvius.

Leucite belongs to the felspathoid family and occurs in igneous rocks, especially lavas, as a product of crystallisation of magmas rich in potash and poor in silica.

On this tray there are several well-developed crystals of leucite, ash-grey in colour, and showing the twenty-four faces of fully developed crystals.

(14) **Haüynite or Haüyne.** Formula complex. Locality, Vesuvius.

This rock is a specimen of lava containing deposits of haüyne. The haüyne crystals are small in size and blue in colour. The best-marked deposit is in the cavity about the centre of the upper surface of this specimen, where a small aggregate mass of blue crystals can be seen as rounded grains with fused-looking surfaces.

Pyroxene Group

For descriptions, see Part I — Petrology — Rock-forming Minerals.

The pyroxene group is composed of a number of species which crystallise in either the orthorhombic, monoclinic, or triclinic systems, and at the same time are closely related in form. All have a fundamental prism with angles of 93° and 87°, yielding nearly a square prism, and parallel to which there is more or less distinct cleavage. Also in other zones the angles show a distinct similarity. The chemical composition is chiefly a metasilicate of calcium, magnesium, and iron, and sometimes aluminium.

(15) **Augite.** Formula $CaMgSi_2O_6+(Mg,Fe)(Al,Fe)_2SiO_6$. Locality, Caithness.

One of the pyroxenes which contains aluminium, being a metasilicate of aluminium, calcium, magnesium, and iron.

On this tray there are several specimens of compact black masses of crystalline augite, showing cleavage planes and a glassy-looking lustre. In some places there is a laminated structure, but the specimens are chiefly in mass.

(16) **Diallage.** Formula $Ca(Mg,Fe)Si_2O_6$. Locality, Cornwall.

This variety of pyroxene is non-aluminous.

There are two samples of crystalline diallage on this tray. They are greyish-green in colour and show a foliated or lamellar structure. On the surfaces of the folia there is a somewhat pearly-looking lustre.

(17) * **Jadeite.** Formula $Na_2O.Al_2O_3.4SiO_2$.

Jade—from the Spanish name *Jade*—originally *Piedra de yjada. Piedra* means stone, *de* of, and *yjada*—now spelt *ijada*—the side or flank—a name given because the stone was supposed to cure pain in the side (*Cent. Dict.*).

This mineral crystallises in the monoclinic system, but it is

generally found in compact masses of interlacing crystalline fibres. There is no cleavage and the fracture is uneven and splintery. The hardness is 7 in the scale, and the sp. gr. is 3·3. In colour it is whitish to green.

On the tray there is a massive, compact specimen of jadeite, pale greenish-grey in colour, and the fractured surface looks uneven and splintery. Part of the specimen is polished.

Jadeite is sometimes valued as a gemstone and it is used for ornamental purposes. The chief source of supply is Upper Burma.

(18) **Pectolite.** Formula $HNaCa_2(SiO_3)_3$. Locality, Ayrshire.

From the Greek *pektos*, put together, +*lithos*, a stone—in reference to its radiating or comb-like structure.

The crystals are monoclinic in form, but the mineral is generally found in acicular aggregates and sometimes in massive fibrous formations. Cleavage is good and the fracture is uneven and brittle. The hardness is 5 in the scale, and the sp. gr. is 2·7. The fractured surface has a silky lustre, and the colour is whitish or greyish. The sample of pectolite on the tray is a massive aggregate of elongated, fibrous-looking crystals with a tendency to radiating structure. The crystals are whitish in colour with a soft, silky-looking lustre.

Pectolite is a secondary product and not a very important mineral.

(19) **Rhodonite.** Formula $MnSiO_3$. Locality, Sweden.

From the Greek *rhodon*, a rose, +*ite*—in reference to its red colour.

The crystals belong to the triclinic system and are usually large and often tabular in habit, but rhodonite is generally found in massive form. Cleavage is good, the fracture is uneven, the hardness is 6 in the scale, and the sp. gr. is 3·6. The lustre is vitreous, and on the cleavage surfaces it is somewhat pearly. In colour it is brownish-red to rose-pink.

On the tray there are two samples of rhodonite, massive in form and brownish-red in colour. The fractured surface is uneven and it has a vitreous lustre. The crystals show distinct cleavage.

(20) **Rhodonite.** Locality, Australia.

A banded specimen of manganite (*see* p. 118) in which the brownish-red bands are composed of rhodonite.

Rhodonite is sometimes used for ornamental purposes.

Amphibole Group (21–28)

For descriptions see Part I — Petrology — Rock-forming Minerals.

The amphibole group comprises a number of species which for the most part resemble each other closely in form, and nearly all crystallise in the monoclinic system. All have a common prismatic form with angles about 124° and 54°, and all have prismatic cleavage. They also agree closely in chemical composition and optical characters.

(21) **Hornblende.** Formula $Ca(Mg,Fe)_3(SiO_3)_4 + Na_2Al_2(SiO_3)_4$. Locality, Caithness.

A heavy, irregular, black-looking rock with some white crystalline deposit on the surface. The large black mass is hornblende, which shows a few cleavage planes and glassy lustre. The flat, black, foliated scales are biotite. The white crystalline deposit is quartz.

(22) **Hornblende.** Locality, Aberdeenshire.

Another specimen showing beautiful, large, black crystals of hornblende with cleavage planes and bright glassy lustre. The white crystalline deposit on some parts of the surface is quartz.

(23) **Tremolite.** Formula $CaMg_3(SiO_3)_4$. Locality, Aberdeenshire.

A heavy, greyish-looking rock in compact, granular-looking massive form. At one or two points on the surface there are some long-bladed radiating crystals to be seen.

(24) **Actinolite.** Formula $Ca(Mg,Fe)_3(SiO_3)_4$. Locality, Switzerland.

On this tray there are two specimens of green-coloured rock, composed essentially of long-bladed crystals of actinolite in radiating form.

(25) **Actinolite.** Locality, Switzerland.

Another specimen of actinolite of the fibrous variety. The fibrous structure is well marked in this case. When the fibres are long, fine, and easily detached from one another it is known as asbestos. When the fibres are very fine and silky it is sometimes called amianthus. The same applies to the fibrous variety of tremolite.

(26) **Asbestos.** Locality, Switzerland.

On this tray there are several small bundles of long, fine, whitish fibres of tremolite, easily separated from each other and readily broken. This is an example of a variety of amphibole or hornblende becoming fibrous in structure and then termed asbestos.

The fibres of asbestos are bad conductors of heat and difficult to burn, hence this material is much used for jacketing or covering steam pipes, etc., and for the manufacture of fire-proof cloth and other refractory articles.

Italy is the chief source of tremolite asbestos.

(27) * **Nephrite.**

From the Greek name *nephros*, a kidney—from its supposed healing properties in diseases of the kidney. Also known as greenstone.

Nephrite is a fine-grained, compact, tough variety of tremolite or actinolite. It has a splintery fracture and a glistening lustre. The hardness is 6·5 in the scale, and the sp. gr. is 3. In colour it varies from white (tremolite) to green (actinolite).

The sample on the tray is a compact, fine-grained variety of actinolite. In colour it is green of different shades. The fractured surface looks splintery, there is a glistening lustre, and in some places there is a tendency to fibrous formation. The polished surface displays various shades of green.

Nephrite is sometimes used as a gemstone and for ornamental purposes. Formerly it was much used by the Maoris in a variety of ways.

The chief sources of nephrite are New Zealand and Turkestan.

(28) **Crocidolite.** Formula $NaFe(SiO_3)_2 . FeSiO_3$. Locality, South Africa.

From the Greek *krokis* (*krokid*), meaning threads in weaving or woof, +*lithos*, a stone—in reference to its fibrous or thready structure—also known as blue asbestos.

The fibres resemble asbestos. They are long, delicate, and easily separated the one from the other. Crocidolite also occurs in massive form. The hardness is 4 in the scale, and the sp. gr. is 3·3. In colour it ranges from lavender-blue to green.

The specimen on the tray shows very distinctly the fibrous structure of the mineral, the fibres being long, some of them delicate, and easily separated the one from the other. The colour is a deep lavender-blue with a shining lustre.

Crocidolite asbestos is not used extensively for textile purposes. Crocidolite is sometimes replaced by quartz as in the Cat's Eye variety of gemstone, and when at the same time oxidation takes place the yellow gemstone known as Tiger's Eye is produced.

The chief source of crocidolite asbestos is South Africa.

(29) **Beryl.** Formula $Be_3Al_2(SiO_3)_6$. Locality, Aberdeen.

From the Greek name *beryllos*—beryl—Latin *beryllus.*

The crystals belong to the hexagonal system and are usually long prisms with vertical striation and terminating in basal planes. It is often found in massive form. There is no distinct cleavage and the fracture is somewhat conchoidal. The hardness is 7·5 in the scale, and the sp. gr. is 2·7. There is a wide range of colour from emerald-green to white, and the lustre is vitreous to resinous.

The specimen on the tray consists of an aggregate of crystals on a massive base. The pale bluish-green to white crystals, showing prismatic form, vertical striation, and a bright glassy lustre, are crystals of beryl. The flat, black, foliated, shining crystals are biotite.

The transparent varieties of beryl are valued as gemstones, the chief of which are emerald and aquamarine.

The principal sources of supply are Columbia, Ural Mountains, and Brazil.

Garnet—for description see Part I—Petrology—Rock-forming Minerals.

(30) **Garnet.** Formula $3FeO.Al_2O_3.3SiO_2$. Locality, Aberdeen.

A heavy, dark, compact, basic rock embedded in the matrix of which are numerous dark brownish-red crystals of garnet—iron-aluminium garnet or almandine. Almandine—a corruption of *Alabandina*—from the place-name *Alabanda* in Asia Minor.

(31) **Garnet.** Locality, Aberdeenshire.

A massive, compact, greenish-black pyroxene rock on the rough surface of which are numerous small, brownish-red crystals of garnet—iron-aluminium garnet.

(32) **Garnet.** Formula $3CaO.Fe_2O_3.3SiO_2$. Locality, Aberdeenshire.

There are two small specimens of aplite rock on this tray embedded in the matrix of which are numerous very dark reddish-brown and black crystals of garnet—calcium-iron garnet or

andradite, or black garnet. Andradite—so named after *Andrada*, a Portuguese mineralogist.

(33) **Garnet.** Locality, Sutherland.

On this tray there are three specimens of mica-schist in the matrix of which are embedded numerous crystals of garnet varying in shade of colour from pale brownish-red to dark brownish-red —iron-aluminium garnet.

(34) **Garnet.** Locality, Ceylon.

A heavy, compact, brownish, cinnamon-coloured rock, consisting essentially of garnet. It has a shining, resinous-looking lustre. From the colour this variety of garnet is sometimes called cinnamon stone.

(35) **Garnet.** Locality, Ceylon.

On this tray there is a large number of small garnets varying in shades of red colour. This variety is termed pyrope—from the Greek *pyropos*, fiery-eyed—in reference to the red colour.

(36) **Garnet.** Locality, Ceylon.

Small specimens of cut and uncut garnets.

Garnets are chiefly valued as gemstones. They are widely distributed, and are found in schists, granites, and in gravels of Ceylon, Brazil, and other places.

(37) **Nepheline.** Formula $K_2Na_6Al_8Si_9O_{34}$. Locality, Vesuvius.

For description see Part I—Petrology—Rock-forming Minerals.

This specimen is a greenish-coloured volcanic rock, opening on the surface of which are several cavities. In one of the cavities there is a deposit of small, white, glassy-looking crystals of nepheline which have a shining vitreous lustre.

(38) **Lazurite**—Lapis Lazuli. Formula $Na_4(NaS_8.Al)Al_2(SiO_4)_3$. Locality, Bucharia, Central Asia.

Lazurite—from an Arabic word, meaning azure—lapis lazuli or azure stone—in reference to its blue colour.

The crystals belong to the cubic system, but this mineral is usually found in massive compact form. The cleavage is imperfect, the fracture is uneven, and the lustre is vitreous. The hardness is 5·5 in the scale, and the sp. gr. is 2·4. In colour it is azure blue or some shade of blue.

The specimen on the tray consists of a dark-coloured, basic-looking, volcanic rock on which there is a deep blue crystalline deposit of lazurite. The white, granular-looking deposit is calcite.

The best varieties of lapis lazuli are valued as gemstones and for ornamental purposes. Formerly it was much used in the manufacture of ultramarine paint.

The chief sources are India, Siberia, and Chile.

(39) * **Scapolite.** Formula complex.

From the Greek *skapos*, a rod, +*lithos*, a stone—a stone with rod-shaped crystals—sometimes termed wernerite.

The crystals are tetragonal and usually prismatic with uneven faces. Massive and granular forms are also common. Cleavage is interrupted, the fracture is sub-conchoidal, and the lustre is vitreous to pearly. The hardness is 5·5 in the scale, and the sp. gr. is 2·7. In colour it varies, but it is often white or greyish.

The specimen on this tray shows a dark base of biotite and hornblende on which are deposited numerous white crystals of scapolite both long and short. The long crystals show prismatic form and uneven faces. There is an interrupted cleavage, and the short crystals show a somewhat conchoidal fracture.

(40) **Topaz.** Formula $(AlF)_2SiO_4$. Locality, Nigeria.

For description see Part I—Petrology Rock-forming Minerals.

Part of a glassy-looking crystalline prism of topaz, clear and transparent, with a very pale bluish-green tinge. The fracture is somewhat conchoidal and there is a bright vitreous lustre. Three prismatic faces are shown, and on one of the faces there is vertical striation.

(41) **Topaz.** Locality, Ceylon.

A specimen of uncut and cut topaz of very pale-yellow colour.

(42) **Zircon.** Formula $ZrO_2 . SiO_2$. Locality, Ceylon.

For description see Part I—Petrology—Rock-forming Minerals.

On this tray there are a few small specimens of zircons of various colours.

Vesuvianite—so named from *Vesuvius*, where it was first found, also termed idocrase—from the Greek *eidos*, form or shape, +*krasis*, a mingling—hence a mingling of forms of crystals.

The crystals belong to the tetragonal system and are generally prismatic or pyramidal. It also occurs in massive form. Cleavage is not well marked, fracture is uneven and brittle, and the lustre is from vitreous to resinous. The hardness is 6·5 in the scale, and the sp. gr. is 3·4. The colour generally is from brown to green, and the streak is whitish.

CASE 4

43) **Vesuvianite.** Formula complex. Locality, Vesuvius.

A basic calcium-aluminium silicate.

The specimen on the tray is a large, irregular, aggregate mass of greyish-brown crystals of vesuvianite—prismatic and pyramidal—showing a vitreous to resinous lustre. There is also a small quantity of pale blue vesuvianite deposit, showing a somewhat conchoidal fracture and compact structure.

(44) **Vesuvianite.**

There are two specimens on this tray showing brown crystals of vesuvianite, with a somewhat conchoidal fracture and a glassy-resinous lustre.

The clear, bright green variety of vesuvianite is cut and polished for gemstones and small ornaments. This mineral was first found in the volcanic rocks of Vesuvius and Monte Somma. It usually occurs in impure limestone from contact metamorphism.

The chief sources are Italy, California, Hungary, and other places.

Andalusite—from the place-name *Andalusia* in Spain, where the mineral is found. A silicate of aluminium.

The crystals belong to the orthorhombic system and usually occur in coarse, nearly square, prismatic forms. It is also found in massive formation. Cleavage is indistinct, the fracture is sub-conchoidal, and the lustre is vitreous. The hardness is 7·5 in the scale, and the sp. gr. is 3. In colour it varies, but it is usually dull grey and often coated with a film of mica, due to alteration. The streak is whitish.

(45) * **Andalusite.** Formula Al_2SiO_5.

An aggregate mass of coarse, reddish-brown crystals of andalusite, some of which show prismatic form and cleavage planes. The white crystalline deposit in the specimen is quartz and the small, flat, shining crystals are mica. Chiastolite or cross-stone is a variety of andalusite which contains a quantity of foreign carbonaceous matter. When cut at right angles to the prism a cross-like figure is generally shown in the section, due to the regular arrangement of the impurities.

Chiastolite—from the Greek *chiastos*, crossed, + *lithos*, a stone—in reference to the cross appearance in section.

Clear and transparent andalusite is sometimes cut and polished

for gemstones. It usually occurs in imperfectly crystallised schists.

The chief sources of supply are Spain, Austria, Brazil, and other countries.

Olivine—for description see Part I—Petrology—Rock-forming Minerals.

(46) **Olivine—Chrysolite.** Formula $(Mg,Fe)_2SiO_4$. Locality, Styria.

Chrysolite—from the Greek name *chrysolithos*, a bright yellow stone.

In a phial on this tray there are numerous small specimens of clear, translucent, pale yellowish-green crystals of olivine. This clear, pale yellowish-green variety is termed chrysolite or precious olivine.

(47) **Olivine.** Locality, Styria.

A granular-looking mass composed essentially of pale yellowish-green crystals of olivine deposited on a base of basalt.

The clear yellowish-green variety of olivine, known as chrysolite, is used for gemstones.

The chief source of this mineral is the Island of St John in the Red Sea. It is found there in cavities in altered basic rocks.

Kyanite—from the Greek *kyanos*, blue—in reference to its blue colour. A silicate of aluminium.

The crystals belong to the anorthic or triclinic system, but they generally occur as long, characteristic, blade-shaped crystals. There is perfect cleavage parallel to the surface of the blades, and transverse to this cleavage there is often fine striation, due to secondary twinning. There are two hardnesses in the crystal. That perpendicular to the length of the crystal is 7 in the scale and in the direction of the length of the crystal it is 5 in the scale, so that the surface can be scratched with a knife in one direction but not in the other. In colour it is generally blue along the centre of the blades and whitish at the margins. The lustre is vitreous.

(48) * **Kyanite.** Formula Al_2SiO_5.

This specimen consists of an aggregate of long, coarse, blade-like crystals of kyanite, arranged in a somewhat columnar structure. It has a pearly lustre, and it is greyish in colour with a faint tinge of blue along some of the blades.

(49) **Kyanite.** Locality, Banffshire.

This tray contains two specimens of kyanite. The one is greyish in colour, and the blade-like fibres are radiating in structure. In the other specimen the fibres are white on the margins, blue in the centres, and arranged in columnar structure.

The clear variety of kyanite is sometimes cut and polished for gemstones. This mineral is associated chiefly with gneiss and mica schists.

Specimens are found in Switzerland, Banffshire, Ireland, and other places.

Datolite —from the Greek *dateisthai*, to divide, +*lithos*, a stone —in reference to the granular structure of the massive form. A basic orthosilicate of boron and calcium.

The crystals belong to the monoclinic system and are usually stout and prismatic, but as a rule they vary somewhat in habit. Datolite also occurs in massive form, granular and compact in structure. The fracture is uneven or sub-conchoidal and brittle. The hardness is 5·5 in the scale, and the sp. gr. is 3. The colour varies, but it is often greyish to pale green and the streak is whitish.

(50) **Datolite.** Formula $H_2O.2CaO.B_2O_3.2SiO_2$. Locality, Midlothian.

In this specimen the whitish crystalline deposit consists of short prismatic crystals of datolite on a base of weathered, dark, basic rock.

(51) **Datolite.** Locality, Midlothian.

A dark, irregular, basic rock, on the surface of which are deposited fairly large, pale-grey prismatic crystals of datolite, mostly broken and showing an uneven fracture and an indistinct cleavage.

Datolite is a secondary mineral and occurs chiefly in veins and cavities in basic eruptive rocks. It is widely distributed and is found in Scotland, Norway, Sweden, and many other districts.

Zoisite—so named by Werner after *Von Zois*, from whom he received a specimen. A basic calcium-aluminium silicate.

The crystals are orthorhombic, generally prismatic, and deeply striated in the vertical direction. It is also found in massive form. Cleavage is good, the fracture is somewhat conchoidal, and the lustre is vitreous. In the scale of hardness it is 6·5 and the sp. gr. is 3·3. The colour varies, but it is often greyish-white to yellowish-brown.

(52) **Zoisite.** Formula $4CaO.3Al_2O_3.6SiO_2.H_2O$. Locality, Inverness.

On this tray there are three small specimens of pale-grey rock, consisting essentially of prismatic crystals of zoisite, showing well-marked cleavage. There is also distinct striation in the long axis of the crystal.

Zoisite is another mineral formed by metamorphic changes in basic igneous rocks containing lime plagioclase. It is widely distributed and found in many areas.

Epidote—from the Greek *epidosis*, increase—in reference to the base of the prism having one side longer than the other. So named by Haüy.

The crystals belong to the monoclinic system and are generally of prismatic shape and elongated in the direction of the symmetry axis. It also occurs in fibrous and granular formations. Basal cleavage is perfect, fracture is uneven, and the lustre is vitreous. In colour it is a peculiar yellowish-green to brownish-green and the streak is greyish. The hardness is 6·5 in the scale and the sp. gr. is 3·4.

(53) **Epidote.** Formula $HCa_2Al_3Fe_2Si_3O_{13}$. Locality, France.

A dark, heavy, basic lava on which is deposited a crystalline mass of yellowish-green epidote, which shows a well-marked cleavage and a glassy to resinous lustre. On the upper surface of the specimen there is a pale-grey crystalline deposit of the mineral showing cleavage and glassy lustre.

(54) **Epidote.** Locality, Shetland.

A dark, heavy, basic rock on which there is a crystalline deposit of yellowish-green epidote. The crystals show a fibrous variety with radiating structure.

(55) **Epidote.** Locality, Dauphiné.

Another sample of epidote consisting of an aggregate of epidote crystals varying in depth of colour from greenish to brownish, and showing cleavage on some surfaces. There is also striation on the prism faces of one or two of the crystals.

The green crystals of epidote are sometimes cut and polished for gemstones.

This mineral is associated with schists and other metamorphic rocks. It is widely distributed and crystals are found in many areas.

Prehnite—so named after *von Prehn* who discovered it. A silicate of aluminium and calcium.

Typical crystals are rare and belong to the orthorhombic system. The crystals generally take the form of compact masses, or globular aggregates with radiating structure. Cleavage is good, the fracture is uneven and brittle, and it has a glassy lustre. The colour usually is pale-green, passing into white or grey. The streak is whitish. The hardness is 6·5 in the scale and the sp. gr. is 2·9.

(56) **Prehnite.** Formula $H_2Ca_2Al_2(SiO_4)_3$. Locality, Dumbartonshire.

A dark, basic, volcanic rock, on which is deposited a pale whitish-grey mass of crystalline prehnite, with a very faint greenish tinge on the fractured surface. The surface of the mass shows somewhat rounded nodules of a pale greyish-brown colour. The fractured surface of the rounded nodules shows an aggregate of crystals with radiating structure.

(57) **Prehnite.** Locality, Renfrewshire.

Another dark, basic rock on which a mass of pale-green prehnite is deposited in botryoidal or grape-like form. Prehnite is of secondary origin and is frequently found in cavities and veins in basic igneous rocks. It is widely distributed and good specimens are found in Cape Colony, Scotland, Lake Superior, and other places.

Hemimorphite—from the Greek *hemi*, half, +*morphe*, form —a crystal showing half its form in reference to the termination of the opposite extremities of the crystals by dissimilar faces.

The crystals belong to the orthorhombic system, and are usually tabular or prismatic, and implanted showing one extremity only. Prism cleavage is perfect, the fracture is uneven, and the lustre is vitreous. The hardness is 5 in the scale, the sp. gr. is 3·5, and the colour is usually white to grey but variable. The streak is white.

(58) **Hemimorphite.** Formula $H_2Zn_2SiO_5$. Locality, Wanlockhead.

A spongy-looking piece of rock of dull greenish colour, with a glassy or vitreous lustre. The irregular projections on the surface show the free ends of numerous small implanted crystals of hemimorphite with vitreous lustre.

(59) **Hemimorphite.** Locality, Leadhills.

In the cavity of a weathered rock there is a deposit of pale brownish-white crystals of hemimorphite in compact form, arranged in small rounded nodules of botryoidal or grape-like formation.

Tourmaline—for description see Part I—Petrology—Rock-forming Minerals.

(60) **Tourmaline.** Formula complex. Locality, Aberdeenshire.

A complex silicate of boron and aluminium.

On this tray are two small pieces of whitish rock embedded in which are small, black, shining crystals of tourmaline, some of which show longitudinal striation.

Staurolite—from the Greek *stauros*, a cross—in reference to the cross-shaped form produced by the regular intergrowth of two crystals in twinned position.

The crystals are orthorhombic and usually prismatic and flattened. The surface is often somewhat rough. Cleavage is distinct but interrupted. The fracture is sub-conchoidal and the lustre is from glassy to resinous. The hardness is 7 in the scale and the sp. gr. is 3·7. In colour it is reddish-brown to brownish-black with a grey streak.

(61) * **Staurolite.** Formula $HFeAl_5Si_2O_{13}$.

A dark-coloured, heavy, micaceous schist, embedded in the matrix of which are large, flattened, prismatic crystals of staurolite, dark-brown in colour and somewhat resinous in lustre.

Apophyllite—from the Greek *apophyllizein*, to strip off its leaves—in reference to the tendency of this mineral to exfoliate.

Apophyllite crystallises in the tetragonal system. The crystals are often in square prisms but the habit varies. It also occurs in massive and lamellar formations. Cleavage is good, the fracture is uneven, and the lustre is vitreous to pearly. In colour it is usually whitish or greenish with a white streak. The hardness is 4·5 in the scale and the sp. gr. is 2·3.

(62) **Apophyllite.** Formula complex. Locality, Hartz.

A silicate of calcium and potassium.

On a mass of calcite there is a greenish crystalline deposit composed essentially of clear, glassy-looking prismatic crystals of apophyllite, showing pyramidal ends and vitreous lustre.

(63) **Apophyllite.** Locality, Iceland.

A dark, basic, volcanic rock, in a cavity of which are deposited clear, glassy-looking, prismatic crystals of apophyllite, some of which have pyramidal ends.

Apophyllite usually occurs as a secondary mineral in basaltic rocks.

Heulandite—named after *H. Heuland*, an English mineral collector.

The crystals belong to the monoclinic system and are usually somewhat flattened prisms, but Heulandite also occurs in globular and granular forms. Cleavage is good, the fracture is uneven, and the lustre is from vitreous to pearly. The hardness is 3·5 in the scale and the sp. gr. is 2·2. The colour varies, but it is usually white, often passing into grey and brown. The streak is white.

(64) **Heulandite.** Formula $H_4CaAl_2(SiO_3)_6 . 3H_2O$. Locality, Iceland.

A silicate of aluminium and calcium.

The surface of this weathered rock is covered with a crystalline crust of heulandite, showing shining, glassy-looking crystals in prismatic form. Some of the faces of the crystals have a pearly lustre.

Brewsterite—named after *Sir David Brewster*.

The crystals belong to the monoclinic system and are generally in prismatic form, cleavage is good, fracture is uneven, the hardness is 5 in the scale, and the sp. gr. is 2·45. In colour it is generally white, tending to yellow and grey.

(65) **Brewsterite.** Formula complex. Locality, Strontian.

A silicate of aluminium, calcium, barium, and strontium. On a weathered-looking rock there is a pale-greyish deposit of crystals of brewsterite. The crystals are prismatic with a somewhat pearly lustre, and they show cleavage planes.

Stilbite—from the Greek *stilbein*, to shine, +*ite*—in reference to the lustre on the cleavage planes.

The crystals belong to the monoclinic system. The prisms generally show cruciform penetration twins and are often grouped in sheaf-like aggregates. Cleavage is perfect, the fracture is uneven, and the lustre is vitreous to pearly. In colour it is generally white but this varies. The hardness is 3·5 in the scale and the sp. gr. is 2·1.

(66) **Stilbite.** Formula complex. Locality, Iceland.

A silicate of aluminium, calcium, and sodium.

On this tray are two specimens of stilbite. The larger one is a crystalline deposit on a volcanic rock. The crystals are elongated, flattened, whitish-grey prisms, showing cruciform penetration twins, grouped in sheaf-like aggregates, displaying cleavage planes and pearly lustre. The smaller specimen is similar in structure, but the crystals are larger, whiter, and more vitreous in lustre.

Chabazite—from the Greek name *chabazios*.

The crystals are rhombohedral and frequently show penetration twins and sometimes complex twinning. Cleavage is fairly good, the fracture is uneven and brittle, and the lustre is vitreous. The hardness is 4·5 in the scale and the sp. gr. is 2·1. In colour it is generally white, though sometimes it is a pinkish-red.

(67) **Chabazite.** Formula complex. Locality, Renfrew.

A silicate of aluminium, calcium, and sodium.

In a cavity of a weathered volcanic rock there is a deposit of pale greyish-white crystals of chabazite. Many of the crystals are square-looking in form and some show penetration twins. The fracture is uneven, there are cleavage planes, and the lustre is glassy.

(68) * **Chabazite.**

A heavy, dark, volcanic rock in a cavity of which there is a white crystalline deposit of chabazite. The crystals are square looking, they show penetration twins, and they have a vitreous lustre.

Analcite—from the Greek *analkis*, feeble—in reference to its weak electric power when heated or rubbed.

Analcite crystals belong to the cubic system and are usually trapezohedra (trapezoid planes). Sometimes it occurs in massive granular form. The fracture is sub-conchoidal, the lustre is vitreous, and the colour is generally white or greyish, though it varies a little. The hardness is 5·5 in the scale and the sp. gr. is 2·2.

(69) **Analcite.** Formula $NaAlSi_2O_6H_2O$. Locality, Ireland.

A silicate of aluminium and sodium.

In the cavity of a dark, basic, volcanic rock there is a crystalline deposit of analcite. The crystals are a clear water colour and show beautiful trapezoid facets. The lustre is bright and glassy.

There is another small specimen on this tray of a similar volcanic rock, and in a small cavity there are analcite crystals of a reddish-brown colour.

(70) * **Analcite.**

In a cavity in an igneous rock there is a white crystalline deposit of analcite. The crystals show trapezoid facets and they have a vitreous lustre. Cleavage is indistinct and the fracture is uneven.

(71) **Analcite.** Locality, Ireland.

Another specimen of analcite deposited on a volcanic rock, showing well-developed white crystals similar to No. 70.

Natrolite—from the Arabic name *natrun*, native carbonate of sodium—in reference to soda contained in the composition.

The crystals are orthorhombic and are usually in the form of slender or acicular prisms in divergent or stellate groups. Cleavage is distinct, the fracture is uneven, and there is a vitreous to pearly lustre. The hardness is 5·5 in the scale and the sp. gr. is 2·2.

In colour it varies, but it is usually white to grey.

(72) **Natrolite.** Formula $Na_2Al_2Si_3O_{10}.2H_2O$. Locality, Perthshire.

A silicate of aluminium and sodium.

A dark, volcanic rock in the cavities of which there are crystalline deposits of natrolite. The deposits are pinkish-brown in colour and consist of aggregates of fine elongated prisms in radiating or stellate formation.

Scolecite—from the Greek *skolex*, a worm, +*ite*—in reference to the worm-like curling movements when the blow-pipe is applied.

A silicate of aluminium and calcium.

The crystals belong to the monoclinic system and are generally elongated, slender, and prismatic in form. Cleavage is good, the fracture is uneven, and the lustre is vitreous to silky. The hardness is 5·5 in the scale and the sp. gr. is 2·3. The colour is usually from white to grey.

(73) **Scolecite.** Formula $CaAl_2Si_3O_{10}.3H_2O$. Locality, Ireland.

A white crystalline mass of scolecite. The crystals are in groups and consist of long, slender prisms in radiating formation. There is distinct cleavage and the crystals show a silky lustre.

(74) **Scolecite.** Locality, Mull.

Another specimen of white crystalline scolecite, showing long, slender, fibrous-looking prisms in radiating groups with silky lustre. The radiating groups are divergent.

Mesolite—from the Greek *mesos*, middle, +*lithos*, a stone—in reference to its intermediate position between natrolite and scolecite.

The crystals are slender, elongated, acicular prisms, aggregated in delicate divergent tufts. In colour they are generally white or whitish grey with a somewhat silky lustre. The sp. gr. is 2·3.

(75) **Mesolite.** Formula complex. Locality, Ireland.

A silicate of aluminium, calcium, and sodium.

On the surface of a dark volcanic rock there is a deposit of white crystalline mesolite. The crystals are fine, elongated, and needle-shaped or acicular, grouped more or less in small divergent tufts with a shining silky lustre.

Mica—for description see Part I—Petrology—Rock-forming Minerals.

Mica Group (76–83)

Muscovite, Biotite, Phlogopite, Lepidolite

The above species of the mica group all crystallise in the monoclinic system, closely approaching rhombohedral and hexagonal symmetry. They all have a perfect basal cleavage, producing very thin, tough, somewhat elastic laminæ or folia. In all the species the angles of the base plane are 60° and 120°.

(76) **Muscovite.** Formula $H_2KAl_3(SiO_4)_3$. Locality, Australia.

An orthosilicate of aluminium and potassium.

The specimens on the tray are large, flat pieces of muscovite or white mica. The cleavage is perfect, and from the surface thin folia or laminæ can be stripped which are flexible and somewhat elastic. The cleavage planes show a pearly, silky lustre and are greyish in colour.

Muscovite is sometimes called potash mica from its chemical composition.

(77) **Muscovite+Biotite.** Locality, Aberdeen.

On a dark basic rock there are deposited thin, flat, silvery-looking crystals of muscovite and thin, flat, black, shining scales of biotite, together with pale-grey, glassy-looking crystals of calcite.

(78) **Biotite.** Formula $(H,K)_2(Mg,Fe)_2(Al,Fe)(SiO_4)_3$. Locality, Aberdeen.

Approximately an orthosilicate of aluminium, iron, magnesium, and potash.

A dark, flat piece of biotite showing cleavage surfaces with shining lustre. From the surface thin, dark folia can be readily detached which are flexible and tough.

(79) **Muscovite+Biotite.** Locality, Hungary.

A quartz rock on the surface of which are deposited thin, whitish. silvery-looking scales of muscovite and dark, thin, shining scales of biotite.

(80) **Biotite+Olivine.** Locality, Germany.

A dark, basic, volcanic rock, on which are deposited thin, black, shining crystals of biotite and some roundish, greenish-coloured crystals of olivine.

(81) **Biotite+Augite.** Locality, Italy.

Another volcanic rock showing thin, black, shining scales of biotite and black, solid-looking crystals of augite.

(82) **Phlogopite.** Formula complex. Locality, Nyassaland.

From the Greek *phlogopos*, fiery-eyed—in reference to its colour.

A silicate of aluminium, magnesium, fluorine, and potassium—sometimes called magnesian mica.

A thin, flat, dark-coloured plate of phlogopite. Cleavage planes are distinct, and on the cleavage surface the lustre is sub-metallic and bright. The colour varies somewhat with position from dark to yellowish-brown. Thin and flexible folia can be peeled from the surface.

(83) * **Lepidolite.** Formula complex.

From the Greek *lepis*, a scale—in reference to the scaly structure of the massive variety.

This variety of mica contains lithium in its composition and is sometimes known as lithia mica. This sample of lepidolite is a pale lilac-coloured rock, composed essentially of compact scaly masses, the cleavages of which give a spangled effect to the specimen.

(84) * **Clinochlore.** Formula $H_8(Mg,Fe)_5Al_2Si_3O_{18}$.

From the Greek *klinein*, to incline, + *chlorós*, yellowish-green —in reference to its colour tending to green or yellowish-green. A hydrated silicate of aluminium and magnesium.

This specimen is a dark greyish volcanic rock on which are deposited crystals of clinochlore. The crystals are tabular and show cleavage planes from which thin flexible folia can be removed. In colour the surfaces are green, varying in shade, and the lustre is somewhat pearly.

The uses of the micas are varied, viz. as insulating plates in electrical apparatus, in certain circumstances as a substitute for glass, in the manufacture of micanite and certain wallpapers, etc.

The micas of commerce are almost entirely muscovite and phlogopite, the former obtained chiefly from India and the latter from Canada. Lepidolite is valued for the extraction of salts of lithium, and sometimes it is cut and polished for ornamental purposes.

Serpentine—for description see Part I—Petrology—Metamorphic Rocks.

Serpentine is usually found in massive form and finely fibrous or granular in structure. It is the hydrated silicate of magnesium. When it occurs in crystals they are pseudomorphs in the form of olivine. In lamellar form it is known as antigorite—from the place-name *Antigorio* in Italy. When there is a fibrous structure it is termed chrysotile, and when it is finely fibrous it is popularly known as asbestos.

(85) **Serpentine.** Formula $H_4Mg_3Si_2O_9$. Locality, Iona.

A rounded, waterworn, compact mass of serpentine showing various shades of green colouring. The fractured surface looks splintery and it feels smooth and somewhat greasy to the touch. With difficulty it can be scratched with a knife.

(86) **Serpentine.** Locality, Iona.

Another compact mass of serpentine, mottled greenish-grey. The fractured surface is splintery, the polished surface shows grey and green mottling, the surface feels smooth and unctuous, and it is easily marked with a knife.

(87) **Serpentine.** Locality, Cornwall.

An irregular, compact mass of serpentine, showing splintery fracture. The colour is dark-green, there is a resinous-looking

lustre, it feels unctuous to the touch, and the streak is pale grey.

Serpentine when cut and polished is used extensively for ornamental purposes. Chrysotile, the fibrous variety, popularly known as asbestos, is employed in a similar manner to the amphibole asbestos.

This mineral is widely distributed and occurs in Cornwall, Switzerland, Tyrol, and many other areas.

Talc—from the Arabic name *Talq*—the hydrated silicate of magnesium.

Good crystals rare; monoclinic or orthorhombic with pseudo-hexagonal symmetry.

Talc usually occurs in platy or foliated forms, aggregated together with perfect cleavage. It also occurs in compact and granular formations. The folia are flexible, but not elastic. In colour it is generally white, pale-green, or brown, with a pearly lustre on the cleavage surface. The feel is greasy and soft, the hardness is 1 in the scale, and the sp. gr. is 2·7.

(88) **Talc.** Formula $H_2O.3MgO.4SiO_2$. Locality, Aberdeen.

A compact, whitish piece of talc showing a sinuous surface and a somewhat fibrous structure. In lustre it is bright and pearly, it has a soft unctuous feel, and it can be marked with the finger-nail.

(89) **Talc.** Locality, Cornwall.

Another specimen of talc showing fibrous structure. It is pale green in colour and exhibits a bright silky lustre. It feels soft and greasy to the touch and can be marked with the finger-nail.

(90) **Talc.** Locality not known.

A specimen of talc of pale rusty colour and silvery lustre. In structure it is laminated. It has a soft unctuous feel and can be marked with the finger-nail.

(91) **Talc.** Locality, Cornwall.

A pseudomorph in talc, brownish in colour with a faint tinge of green. It has a soft unctuous feel and can be marked with the finger-nail. The lustre is somewhat resinous.

Talc is an alteration product of magnesian minerals, and steatite or soapstone is a variety of it. It is widely used for marking cloth, for jets of gas-burners, for furnace linings, etc. In powdered form it is valued for toilet powders, for preserving rubber, for dry lubricants, etc.

Garnierite—named after *Jules Garnier* who first discovered it in New Caledonia. A hydrous silicate of magnesium and nickel.

This mineral is usually found in amorphous and compact formations, but it sometimes occurs in the form of earthy masses. The fracture is uneven, the hardness about 3 in the scale, and the sp. gr. about 2·5. In colour it is generally pale green to dark green with a dull lustre.

(92) **Garnierite.** Formula $H_2(Ni.Mg)SiO_4$. Locality, New Caledonia.

A heavy, conglomerate-looking rock, consisting of a fine matrix, friable and brittle, coloured green of various shades, with a dul lustre. In this matrix are embedded numerous small, pebbly-looking stones of various sizes. The green material is garnierite which is amorphous and friable.

Garnierite is valued as an important ore of nickel and is found chiefly in New Caledonia.

Kaolinite—a corruption of *Kauling*, a place in China where it is obtained—*Kaolin*, *+ite*. A hydrated silicate of aluminium.

The crystals are monoclinic and are usually in thin rhombic or hexagonal scales or plates, frequently found in clay-like masses, compact or friable. Basal cleavage is perfect and there is a pearly lustre on the cleavage plane. The hardness is 2 in the scale and the sp. gr. is 2·6. In colour it varies from white to brown.

(93) **Kaolinite.** Formula $H_4Al_2Si_2O_9$. Locality, New South Wales.

A square white block of kaolin which feels smooth and soapy to the touch. It is easily scratched with the finger-nail, leaving a white streak. It is soft and friable.

(94) **Kaolinite.** Locality, Cornwall.

A phial containing a sample of white kaolin powder. Kaolin, especially the fine qualities, is much valued in the manufacture of porcelain and china. The clayey variety is much used in making pottery, stoneware, bricks, etc.

Kaolin is the result of the decomposition of rocks containing aluminium compounds, as in the felspars of granite, gneiss, and other rocks. It is therefore very widely distributed.

Chrysocolla—from the Greek *chrysos*, gold, +*kolla*, glue—in reference to the name of the material used in soldering gold. A hydrated silicate of copper.

Cryptocrystalline in structure and often opal or enamel-like in texture, it is generally found lining or filling seams. The fracture is conchoidal with a vitreous to dull lustre. In colour it ranges from green to blue. The hardness varies from 2 to 4 in the scale and the sp. gr. is about 2·2.

(95) **Chrysocolla.** Formula $CuSiO_3 . 2H_2O$. Locality, Leadhills.

A heavy, dark, basic rock on the surface of which is a deposit of chrysocolla. In colour this crust deposit is various shades of blue, and the dark-blue portion has an enamel-like structure. It shows sub-conchoidal fracture with a dull lustre. It can be marked with a knife, leaving a whitish streak.

(96) **Chrysocolla.** Locality, Cornwall.

On this tray there are two specimens. The larger one is a mass of cream-coloured barite or heavy spar, and on this barite there is a greenish deposit of chrysocolla. The small specimen is a sample of dark green chrysocolla.

Titanite or Sphene—for description see Part I—Petrology—Rock-forming Minerals (p. 18).

(97) **Titanite**—from the name titanium (p. 120), +ite. Locality, Norway.

A silicate of titanium and calcium.

This specimen is a lump of brownish-coloured orthoclase in which are embedded several large, blackish-brown, prismatic crystals of sphene or titanite. They show a dull resinous lustre, and they can be marked with a knife, leaving a pale-grey streak.

Sphene is often associated with felspathic igneous rocks and is more common in the plutonic type than in the volcanic form. It is a widespread mineral.

CHAPTER XI

The Phosphates, Arsenates, Vanadates, Sulphates, Molybdates, and Tungstates. Case 4

Group VII.—Phosphates, Arsenates, Vanadates

When phosphorus combines with oxygen and hydrogen in the proportions represented by the formula H_3PO_4 phosphoric acid is produced, and when the hydrogen of the acid is replaced by a metal, a salt called a phosphate is the result—thus H_3PO_4 acid, $Ca_3(PO_4)_2$ salt, where calcium replaces hydrogen and forms the phosphate of lime or calcium.

Allied to the phosphates and isomorphous with them are the arsenates and vanadates, where arsenic and vanadium take the place of phosphorus, and where, though metallic elements, they play the part of acids.

Apatite Group

Apatite, Pyromorphite, and Vanadinite

In all three the typical form is the hexagonal prism and hexagonal pyramid. They have one principal plane of symmetry—the plane of the horizontal axes—and chemically they are phosphates, arsenates, or vanadates of calcium or lead+chlorine or fluorine.

Case 4

(1)* **Apatite.** Formula $(CaF)Ca_4(PO_4)_3$. Essentially a phosphate of calcium or lime+chlorine or fluorine.

For description see Part I—Petrology—Rock-forming Minerals.

The two specimens of apatite on this tray are both composed of flat, tabular crystals. One is dark-green and the other bluish-green in colour. Both show resinous lustre, both have an uneven fracture, and both can be marked with a knife, leaving a pale-grey streak.

Phosphates of calcium or lime are extensively used in the manufacture of artificial manures, especially the variety termed phos-

phorite or rock phosphate. Many of the recent rock phosphates have been derived from the action of bird guano on limestone.

Pyromorphite—from the Greek *pyr*, fire, + *morphe*, form, + *ite* in reference to the crystalline form the fused globule assumes on cooling.

The crystals belong to the hexagonal system, usually prismatic in form, but often barrel-shaped in outline with tapering ends. Sometimes they are globular or reniform. The fracture is uneven, the lustre resinous, the hardness is 3·5 in the scale, and the sp. gr. is about 7. The colour varies, but is often green, yellow, or brown of different shades.

(2) **Pyromorphite.** Formula $3Pb_3P_2O_8 . PbCl_2$. Locality, Cumberland.

There are four specimens of pyromorphite on this tray.

(*a*) Showing prismatic crystals tapering towards the end. The fracture is sub-conchoidal, the colour is pale-green, and the lustre is resinous.

(*b*) Showing small globular deposits, green in colour, and a spangled appearance.

(*c*) Showing a somewhat columnar structure, yellowish-green in colour with a dull lustre.

(*d*) A deposit somewhat granular in structure, showing an ochreous yellowish-orange colour with a dull lustre.

Pyromorphite is formed by an alteration of galena and generally occurs in veins of lead ore.

Vanadinite—from *Vanadium*, a name given by Sefström to a metal he discovered in 1830 from *Vanadis*, a Goddess of Scandinavian mythology.

Crystals hexagonal-pyramidal. The prisms have generally smooth faces and sharp edges. They are also found in rounded forms as in implanted globules or incrustations. The fracture is uneven and the lustre is somewhat resinous on the fractured surface. The hardness is 2·8 in the scale and the sp. gr. is about 7. In colour it varies from ruby red to reddish-brown.

(3) **Vanadinite.** Formula $3Pb_3V_2O_8 . PbCl_2$. Locality, Leadhills.

On the surface of a mass of calcite there are implanted numerous small globules of vanadinite, brownish in colour. The large pale-grey crystals are calcite.

This mineral is useful as a source of vanadium.

Lazulite—from the Arabic *Azul*, meaning heaven—in reference to the blue colour, or *lazuli*, azure.

The crystals belong to the monoclinic system and are generally pyramidal in habit. It is also found in massive form from granular to compact. The fracture is uneven and the lustre is vitreous. The hardness is 5·5 in the scale and the sp. gr. is 3·1. In colour it is usually azure blue.

(4) * **Lazulite.** Formula complex.

A phosphate of iron, aluminium, and magnesium.

There are two specimens of lazulite on this tray. In the phial there are several pieces of dark blue lazulite in massive form. The free specimen is dark blue lazulite, also in massive form, on a base of pale grey calcite.

Vivianite—named after *J. H. Vivian*, a mineralogist.

The crystals belong to the monoclinic system, are prismatic in form, and are frequently arranged in stellate groups. It also occurs in reniform and globular formations. Cleavage is perfect, and the lustre on the cleavage plane is pearly. The crystals are easily bent and distorted. The hardness is 1·5 in the scale and the sp. gr. is 2·6. Crystals when pure and unexposed are colourless, but when exposed to air and light they quickly become blue, due to partial alteration of iron oxide. The characteristic colour is indigo blue.

(5) **Vivianite.** Formula $Fe_3(PO_4)_2 . 8H_2O$. Locality, Falkirk.

The free specimens on this tray represent concretions of vivianite or phosphate of iron taken from mudstone. They are blue in colour, soft and friable in texture—also known as Blue-Iron Earth. In the small box there are numerous pieces of dark-blue vivianite, obtained from the decomposed bones of the red deer.

Turquoise—from the old French name *Turquoise*, sometimes called Turkish stone—in reference to its being brought through Turkey from Persia.

Turquoise is usually found in massive form, amorphous or cryptocrystalline, and often reniform or incrusting in structure. The hardness is 5·5 in the scale and the sp. gr. is 2·8. In colour it varies from sky blue to apple green, with a somewhat waxy lustre. This is a hydrated phosphate of aluminium, coloured by copper and iron compounds.

(6) * **Turquoise.** Formula complex.

In a small phial are numerous semi-globular pieces of turquoise, pale greenish-blue in colour with a somewhat waxy lustre. On the tray there are two small specimens of rock, showing veins of pale bluish-green turquoise.

Erythrite—from the Greek *erythros*, red—in reference to its colour. Also known as Cobalt Bloom.

The crystals are monoclinic, usually prismatic, and vertically striated. It also occurs in globular and reniform formations. Cleavage is perfect, and the lustre is from pearly to vitreous though sometimes it is dull. The hardness is 2 in the scale and the sp. gr. is 3. The colour is generally from crimson to peach-red.

(7) **Erythrite.** Formula $Co_3As_2O_8 . 8H_2O$. Locality, Saxony.

A hydrous arsenate of cobalt.

On the surface of a mass of dark-coloured quartz there are deposited numerous beautiful, prismatic crystals of erythrite or cobalt bloom, striated in the vertical direction. The colour is pinkish crimson and the lustre is vitreous. The crystals are arranged in stellate form.

Uraninite—from *Uranium*, so called in allusion to the planet *Uranus*—also known as Pitchblende.

The crystals belong to the cubic system, but they are rare. It is usually found in massive form and in botryoidal structure, or in grains. The fracture is sub-conchoidal and brittle, the lustre is from metallic to dull or pitch-like, and the colour is from grey to brownish-black. It is a uranate of uranyl, lead, and rare metals.

(8) **Uraninite.** Formula complex. Locality, Bohemia.

A heavy, dark, pitch-looking specimen of uraninite in massive form, showing somewhat conchoidal fracture and a dull metallic lustre. In this form it is probably amorphous.

Radium was first discovered in this mineral, and it is supposed that the radium and helium present in it are products of decomposing uranium. Uraninite is sometimes described as an oxide of uranium.

Group VIII.—Sulphates, Molybdates, and Tungstates

When sulphur combines with hydrogen and oxgyen in the definite proportion of H_2SO_4, the result is the production of

sulphuric acid. When the hydrogen of the acid is replaced by a metal, a salt is produced termed a sulphate. Thus H_2SO_4 acid, $BaSO_4$ the salt, sulphate of barium or Barite—sometimes called Heavy Spar—in which barium takes the place of hydrogen.

The closely related elements Molybdenum and Tungsten (the same as Wolframium, hence the symbol W) act in a similar manner, though they are metals, producing molybdates and tungstates—thus, H_2MoO_4 acid, $PbMoO_4$ salt, molybdate of lead or Wulfenite, in which lead replaces hydrogen in the molybdic acid.

Barite or Barytes—from the Greek *barus*, heavy—in reference to the weight of the mineral. The sulphate of barium.

The crystals belong to the orthorhombic system. They are usually tabular and united in converging groups. It also occurs in prismatic, crested, and other forms. Cleavage is perfect, the fracture is uneven and brittle, and the lustre as a rule is vitreous. The hardness is about 3 in the scale and the sp. gr. about 4·5. The colour is often white, but grey, brown, and other shades are not uncommon.

(1) **Barite or Barytes.** Formula $BaSO_4$. Locality, Leadhills.

A large, heavy, white rock, composed chiefly of thick, coarse laminæ of barite, joined together in convergent structure. It shows well-marked cleavage, an uneven fracture, and a somewhat pearly lustre. This mineral is softish and is easily marked with a knife, leaving a white streak. Among the laminæ there are small shining deposits of copper and iron pyrites.

(2) **Barite.** Locality, Leadhills.

A sample of white, massive barite with glassy lustre in which the laminæ assume a crested form.

(3) **Barite.** Locality, Wanlockhead.

Another specimen of white barite in massive form, showing cleavage and thick laminæ, with glassy lustre.

(4) **Barite.** Locality, Leadhills.

A specimen of barite, greyish white in colour with glassy lustre, showing crystalline formation, with sloping chisel-like faces at the top of the crystal.

(5) * **Barite.**

A crystal of clear, transparent, colourless barite. In some positions it shows a beautiful display of colours on the fractured surface.

Anglesite—so named from *Anglesea* where it was first found. The sulphate of lead.

The crystals belong to the orthorhombic system and are usually in tabular or prismatic form. It also occurs in massive and granular formations. The fracture is uneven and brittle, and the lustre is resinous to vitreous. The hardness is about 3 in the scale and the sp. gr. is 6. In colour it is often white, but it may be grey or some other shade of colour.

(6) **Anglesite.** Formula $PbSO_4$. Locality, Leadhills.

A mass of eroded galena on the surface of which crystals of anglesite are deposited. The crystals are small and show both prismatic and tabular forms. In colour they are white, and some of them have a tinge of yellow. There are also some greyish-looking crystals of cerussite on the specimen.

Anglesite is formed from the decomposition of galena and is frequently found in lead veins.

Lanarkite—from the place-name *Lanark*, *+ite*. A basic sulphate of lead.

The crystals belong to the monoclinic system and are usually prismatic in form. It also occurs in massive formation. As a rule the crystals are pale-grey or greenish-white in colour.

(7) **Lanarkite.** Formula Pb_2SO_5. Locality, Leadhills.

A specimen from a cavity in a lead vein composed essentially of an aggregate of pale-grey crystals of lanarkite, at some points showing a pale yellowish-green tinge. The small lead-grey mass towards the side of the specimen with shining surfaces is galena.

This mineral is another result of decomposing lead.

Leadhillite—from the place-name *Leadhills* where it is found. A sulphato-carbonate of lead.

The crystals are monoclinic in system and usually tabular in form. Cleavage is perfect, the fracture is conchoidal, and the lustre varies from pearly to resinous. The colour is usually white, sometimes passing to green and yellow. The hardness is 2·5 in the scale and the sp. gr. is 6·3.

(8) **Leadhillite.** Formula $4PbO.SO_3.2CO_2.H_2O$. Locality, Leadhills.

This specimen shows flattened or tabular crystals of leadhillite. They are pale-grey in colour with a tinge of very pale-green. The specimen also contains some crystals of pyromorphite.

A mineral of secondary origin, derived from galena.

Celestite—from the Latin *cœlestis*, celestial—in reference to the pale-blue colour often present.

A sulphate of strontium.

The crystals are orthorhombic and usually found in tabular or prismatic form. It also occurs in fibrous and globular structure. Cleavage is perfect, the fracture is uneven, and the lustre is from pearly to vitreous. The hardness is 3·5 in the scale and the sp. gr. is 3·9. In colour it is usually white with a faint bluish tinge.

(9) **Celestite.** Formula $SrSO_4$. Locality, Sicily.

A large, crystalline mass of celestite, composed of an aggregate of prismatic crystals, ending in different forms of prism facets. In colour they are white with a very faint tinge of blue. There are well-marked cleavage planes, showing a somewhat pearly lustre. The yellow deposit on the specimen is sulphur.

(10) **Celestite.** Locality, France.

Another specimen of celestite composed of an aggregate of square-looking, flat, tabular crystals of pale yellowish-brown colour with vitreous lustre.

(11) **Celestite.** Locality, Italy.

A crystalline mass of celestite with markedly irregular surface. The projections on the surface are prismatic crystalline aggregates showing beautifully faceted ends. The colour is white with a faint tinge of blue and a glassy lustre. The specimen also shows a few yellow crystalline deposits of sulphur.

Celestite is used in the manufacture of fireworks and in the refining of sugar. It is usually associated with limestone and also with metalliferous ores, as galena, etc.

Anhydrite—from the Greek *anhydros*, without water.

A sulphate of calcium or lime.

The crystals belong to the orthorhombic system, but they are not common. It usually occurs in massive form and sometimes in lamellar, fibrous, or granular formations. Cleavage is good, the fracture is uneven or splintery, and the lustre is vitreous. In colour it is frequently white, but it may be greyish or bluish. The hardness is 3·5 in the scale and the sp. gr. is 2·9.

(12) * **Anhydrite.** Formula $CaSO_4$.

A specimen of crystalline anhydrite in massive form, showing a splintery fracture, cleavage, a vitreous lustre, and a bluish

colour. It is readily marked with a knife, leaving a greyish-white streak.

Anhydrate, by the absorption of water, changes to gypsum.

Gypsum—from the Greek name *gypsos*—the hydrous sulphate of calcium.

The crystals are monoclinic and are usually flattened or prismatic. It is also common in massive form with foliated, granular structure. Cleavage is well marked, fracture is uneven, and the lustre is from pearly to vitreous. The hardness is 2 in the scale and the sp. gr. is 2·3. There is a wide range in colour but it is usually white.

(13) **Gypsum.** Formula $CaSO_4 . 2H_2O$. Locality, Oxford.

The hydrous sulphate of calcium.

On this tray there are several specimens of flattened, clear, crystalline prisms of gypsum. They are readily marked with a knife, leaving a whitish streak. The large crystal in the centre is an example of twinning, showing the usual swallow-tail twins.

(14) **Gypsum.** Locality, France.

A brownish-coloured specimen composed of flat, tabular crystals of gypsum, some of which are striated in the length of the crystal. On the flattened surface the lustre is pearly, and on the edge it looks glassy or vitreous.

(15) **Gypsum—Alabaster.** Locality, Italy.

A large piece of compact, fine-grained, white gypsum. This fine-grained white variety is known as alabaster.

(16) **Gypsum—Selenite.** Locality, Australia.

A specimen of clear, transparent, foliated gypsum, with a somewhat pearly lustre. This crystalline variety is also termed selenite—from the Greek *selene*, the moon—in reference to its moonlight-like lustre.

Gypsum is used in many ways. The fine-grained variety—alabaster—is valued in sculpture and for making slabs for decorative purposes; the clear, transparent variety—selenite—is employed for optical purposes; and the fine fibrous variety—satin spar—is sometimes cut and polished for ornaments of various kinds. The coarser variety is much used and valued in the form of plaster of Paris; it is added to plaster and cement of various kinds, and it is useful sometimes as a soil dressing, etc.

Gypsum is widely distributed and is found in all geological

horizons. In places it occurs in beds, and has probably been deposited there from solution in lake waters, or partly by the absorption of water by the anhydrous variety.

The chief sources of supply are the United States, France, and other places.

Alunite—contracted from Aluminilite. A basic hydrous sulphate of aluminium and potassium -also called alumstone.

The crystals belong to the hexagonal system, but it is usually found in massive form with microcrystalline texture. There is basal cleavage, the fracture is uneven, and the lustre is vitreous. The hardness is 4 in the scale and the sp. gr. is 2·7. In colour it is white to greyish and sometimes pinkish.

(17) **Alunite.** Formula $K_2O.3Al_2O_3.4SO_3.6H_2O$. Locality, Australia.

A fine-grained, compact specimen of alunite in massive form. The fracture is shallow conchoidal, the colour is white, and the lustre is somewhat dull.

Alunite is valued in the manufacture of alum. The chief sources of supply are Australia, Italy, and Spain.

Wolframite—from the German name *Wolfram*, tungsten +*ite*. A tungstate of iron and manganese.

Crystals are not very common and are monoclinic. They usually occur in tabular or prismatic form, but this mineral is most frequently met with in massive form of granular or columnar structure. The cleavage is good, the fracture is uneven, and the lustre is somewhat metallic. The hardness is 5·5 in the scale and the sp. gr. is 7·4. The prismatic face is frequently striated in the vertical direction.

(18) **Wolframite.** Formula $(Fe,Mn)WO_4$. Locality, Saxony.

A heavy, dark, somewhat pitchy-looking, crystalline mass, showing cleavage surfaces and striation on the prismatic faces in the vertical direction. The cleavage planes have a bright, shining lustre.

Wolframite is useful as an ore of tungsten, which is much valued in the manufacture of steel filaments for electric lamps, and as a substitute for platinum in the manufacture of contact points. It is often associated with ores of tin and other minerals.

The chief sources of supply are China, Bohemia, Siberia, etc.

Scheelite—named after the Swedish chemist *Scheele*, who discovered tungstic acid in this mineral. The tungstate of calcium.

The crystals belong to the tetragonal system and are usually octohedral or tabular, but this mineral is more commonly found in massive formation. The cleavage is good, the fracture is uneven and brittle, and the lustre is vitreous. The hardness is 5 in the scale and the sp. gr. is 6. In colour it is generally white or yellowish, but this varies.

(19) **Scheelite.** Formula $CaWO_4$. Locality, U.S.A.

On the surface of a crystalline rock (quartz) there is a brownish-coloured deposit consisting of flattened or tabular crystals of scheelite. It shows cleavage planes with glassy lustre.

Scheelite is useful as an ore of tungsten. It is usually associated with crystalline rocks, and is often found in connection with cassiterite and other minerals. It is widely distributed and found in many countries.

Wulfenite—named after *Wulfen*, an Austrian mineralogist. The molybdate of lead.

The crystals are tetragonal in system and usually occur in platy or tabular form. Sometimes they are found prismatic and pyramidal in shape. It is also met with in massive formation. Cleavage is fairly good, the fracture is uneven and brittle, and the lustre is resinous. The hardness is 3 in the scale and sp. gr. is 7. In colour it is usually a shade of yellow, brown, or red.

(20) **Wulfenite.** Formula $PbMoO_4$. Locality, Carinthia.

A heavy, yellowish-brown, resinous-looking specimen, showing in aggregate some yellowish-brown, flat, tabular crystals of wulfenite. The fractured surface is uneven and there is a somewhat waxy lustre. The crystals can be readily marked with a knife, leaving a pale greyish streak.

Wulfenite is useful as an ore of molybdenum. It usually occurs in veins with ores of lead. It is widely distributed, but it is not a very important mineral.

CHAPTER XII

Group IX.—Collection of Minerals from Leadhills

Case 4

(1) A large, weathered, brecciated-looking rock on the surface of which the following crystals are found: (*a*) barytes—large, white, shining crystals showing cleavage planes; (*b*) linarite—small, dark-blue crystals; (*c*) caledonite—small, green crystals; (*d*) cerussite—grey crystals in the cavities.

(2) A brown-coloured rock on the surface of which are beautiful specimens of green-coloured, prismatic crystals of pyromorphite.

(3) A heavy, brecciated mass showing on its surface (*a*) cerussite crystals—black in colour; (*b*) cerussite crystals—white in colour.

(4) A sample of graphite—a black, somewhat earthy-looking mass with a dull lustre.

(5) There are two specimens on this tray each showing dark-blue and pale-blue deposits of chrysocolla. In some of the deposits there is a greenish tinge.

(6) An irregular, brown-coloured rock showing small, dark-brown, crystalline-looking structures of pyrolucite.

(7) A phial containing small nuggets of gold from Wingate Glen, Leadhills.

(8) A large complex specimen showing (*a*) large, pale-grey crystals of calcite; (*b*) small, irregular, whitish crystals of dolomite; (*c*) crystals of copper pyrites showing iridescent colours.

(9) A black, shining, crystalline mass of sphalerite or zinc blende on the surface of which are a few pale-coloured crystals of calcite and some small iridescent crystals of copper pyrites.

(10) On this tray there are two specimens of pyromorphite showing a greenish and yellowish-ochry colour.

(11) Two specimens of pyromorphite—one showing pyromorphite surrounding a lead kernel, and the other showing a cavity in pyromorphite from which the lead kernel has been removed.

(12) An aggregate of whitish dolomite crystals showing a non-translucent, vitreous lustre.

(13) A brownish-coloured specimen showing a deposit of vanadinite in small globular formation.

(14) A pale-greyish specimen of rock in a cavity of which are crystals of anglesite, tabular in form and pale yellowish-white in colour.

(15) A large specimen of barytes showing white and pinkish-brown banded structure. Cleavage planes are well marked.

(16) This specimen consists of large, whitish crystals of calcite, containing numerous small, black grains of foreign matter, on a base of nail-head variety of quartz.

(17) A large, irregular, variegated specimen containing crystals of the following minerals : (*a*) susannite—so named from Susanna Mine, Leadhills—a sulphato-carbonate of lead ; (*b*) leadhillite—so named from Leadhills—closely resembles susannite and is also a sulphato-carbonate of lead ; (*c*) lanarkite—from the place-name Lanark—a basic sulphate of lead.

(18) A sample of galena showing the changed character of the mineral produced by percolating water.

(19) A brownish specimen showing brownish and whitish deposits of hemimorphite in rounded or globular formations.

(20) A sample of aragonite showing thin, elongated crystals in radiating form.

(21) A clear crystalline mass of barite showing cleavage and vitreous lustre.

(22) A grey, compact specimen of elvanite, embedded in the matrix of which are several small, square, shining crystals of iron pyrites.

(23) A specimen consisting of (*a*) white quartz crystals with pyramidal ends ; (*b*) copper pyrites showing iridescent colours.

(24) A compact, grey felsite in the matrix of which are embedded large crystals of iron pyrites.

(25) On this tray there are three specimens showing (*a*) linarite—the dark blue crystals—a basic sulphate of lead and copper ; (*b*) caledonite—the green crystals—a basic sulphate of lead and copper.

(26) Three specimens containing flat, pale greenish-coloured crystals of leadhillite.

(27) Two specimens showing (*a*) greenish deposit of malachite ; (*b*) greenish-yellow deposit of hemimorphite.

Group X.—Economic Rocks

Cases 5 and 6

Economic rocks may be described as rocks which are worked for gain in regard to the supply of human needs and comforts.

The following groups of economic rocks are here represented.

A. *Coal or Carbonaceous Rocks*

For description see Part I, Organically-formed Rocks—rocks derived from plant remains.

(1) Coal—common. Locality, Midlothian.

(2) Coal—bituminous. Locality, Wollongong.

(3) Coal—bituminous. Several samples on this tray. Locality, Gumbles, New South Wales.

(4) Coal—torbanite. Locality, New South Wales.

(5) Coal—iridescent. Locality, Fifeshire.

(6) Coal—lignite or brown coal. Locality, Germany.

Lignite may be regarded as an intermediated stage in the development of true Coal.

B. *Auriferous or Gold-bearing Rocks*

For description see Part II, Mineralogy—The Native Elements.

(7) Auriferous rock—conglomerate. Locality, South Africa.

(8) Auriferous rock—conglomerate. Locality, Transvaal.

(9) Auriferous rock—conglomerate. Locality, Transvaal.

(10) Auriferous rock—conglomerate. Locality, South Africa.

(11) Auriferous and pyritous quartz. Locality, Australia.

(12) Auriferous and pyritous quartz. Locality, Australia.

(13) Auriferous and pyritous quartz. Locality, Australia.

(14) Auriferous quartz. Locality, Australia.

(15) Auriferous granite. Locality, Australia.

(16) Auriferous quartz. Locality, New Zealand.

(17) Auriferous quartz. Locality, New Zealand.

(18) Auriferous quartz. Locality, New South Wales.

(19) Auriferous chalcedony with malachite. Locality, Australia.

C. *Argentiferous or Silver-bearing Rocks*

For description see Part II, Mineralogy—Native Elements and Minerals.

(20) Argentiferous siderite. Locality, New South Wales.

(21) Argentiferous cerussite with galena. Locality, New South Wales.

(22) Argentiferous cerussite with iron. Locality, New South Wales.

(23) Argentiferous sulphide of copper and iron. Locality, New South Wales.

(24) Argentiferous galena. Locality, Adelaide.

(25) Argentiferous galena laminated. Locality, New South Wales.

(26) Argentiferous galena. Locality, New South Wales.

(27) Argentiferous gossan. Locality, New South Wales.

For description of gossan see Part I, Miscellaneous collection (p. 62).

(28) Argentiferous quartz. Locality, New South Wales.

D. *Copper-bearing Rocks*

For description see Part II, Mineralogy—Elements, Sulphides, Oxides, and Carbonates.

(29) Copper—native. Locality, New South Wales.

(30) Cuprite with malachite. Locality, New South Wales.

(31) Cuprite with malachite. Locality, New South Wales.

(32) Copper pyrites. Locality, New South Wales.

(33) Copper pyrites—copper and iron sulphide. Locality, New South Wales.

(34) Copper pyrites. Locality, New South Wales.

(35) Chalcopyrites—several samples. Locality, New South Wales.

(36) Chalcopyrites—two samples. Locality, New South Wales.

(37) Copper ore—stanniferous. Locality, New South Wales.

(38) Copper pyrites with malachite. Locality, New South Wales.

(39) Malachite. Locality, New South Wales.

E. *Iron-bearing Rocks*

For description see Part II, Mineralogy—Sulphides and Oxides.

(40) Hematite—iron ore. Locality, New South Wales.

(41) Hematite—several samples. Localities various.

(42) Hematite with quartz. Locality, New South Wales.

(43) Ironstone. Locality, Leadburn.

(44) Limonite. Locality, New South Wales.

(45) Limonite. Locality, New South Wales.

(46) Limonite. Locality, New South Wales.

(47) Iron pyrites. Locality, New South Wales.

(48) Iron pyrites—two samples. Locality, New South Wales.
(49) Hematite. Locality, New South Wales.
(50) Pyrites with quartz. Locality, New South Wales.
(51) Pyrites with calcite. Locality, New South Wales.

F. *Lead-bearing Rocks*

For description see Part II, Mineralogy—Sulphides.

(52) Lead ore—galena. Locality, Australia.
(53) Galena with calcite. Locality, Wanlockhead.
(54) Galena with quartz. Locality, Leadhills.
(55) Galena—massive. Locality, Leadhills.
(56) Galena with cerussite. Locality, New South Wales.

G. *Antimony-bearing Rocks*

For description see Part II, Mineralogy—Sulphides.

(57) Stibnite. Locality, New South Wales.
(58) Stibnite. Locality, New South Wales.

H. *Arsenic-bearing Rocks*

For description see Part II, Mineralogy—Sulphides.

(59) Arsenopyrites or mispickel. Locality, New South Wales.

I. *Zinc-bearing Rocks*

For description see Part II, Mineralogy—Sulphides.

(60) Zinc blende or sphalerite. Locality, Leadhills.
(61) Zinc blende with calcite crystal. Locality, Leadhills.

K. *Shale—bituminous*

For description see Part I, Rocks derived from plant remains.

(62) Shale—bituminous. Locality, Broxburn.

L. *Asphalt*

(63) Asphalt—bitumen or mineral pitch. Locality, Trinidad.

This substance has a conchoidal, shining fracture and consists of a mixture of hydrocarbons which are partially oxidised. The sample is from the Asphalt lake in Trinidad.

M. *Asbestos*

For description see Part I, Rock-forming Minerals, and Part II, Mineralogy—Silicates.

(64) Asbestos. Locality, Italy.

N. *Mica*

For description see Part I, Rock-forming Minerals, and Part II, Mineralogy—Silicates.

(65) Muscovite—white or potash mica. Locality, Switzerland.

PART III—PALÆONTOLOGY

CHAPTER XIII

Palæozoic Group. Cases 7, 8, and 9

In sedimentary rocks of all kinds the various deposits or strata are laid down one upon the other in a more or less horizontal position, and therefore the lower strata are deposited before the upper strata. Hence the lower strata are older than the strata above them. This fact is termed the law of superposition and is the foundation of geological chronology. Other methods are employed for determining the chronology of rocks, but they must all be based originally on the observed order of superposition. Take, for example, two specimens of sandstone from two widely divided areas. There will be nothing in the structure of these samples of sandstone, so far as the mineral constituents are concerned, to tell us whether they belong to the same horizon or platform in geological chronology, or whether one was deposited in the Silurian period and the other in the Jurassic period.

When we do not see the superimposed strata before us we require something more to help us in this chronological study. This help is supplied to us in the form of organic remains, and it depends upon the law 'That the order of succession of plants and animals has been similar all the world over.'

Now let us apply the law of superposition, and we find that in a formation of rock containing organic remains the organic remains contained in this formation must be younger than the organic remains contained in the formations below it, and older than the organic remains contained in formations above it.

This system has been laboriously, elaborately, and carefully worked out in a great series of stratified formations, and certain conclusions have been reached. Speaking broadly, they are as follows, viz. :—

1. That species in older deposits differ from species in later deposits.

2. That the older species generally die out and are replaced by younger forms.

3. That well-marked geological formations or deposits are distinguishable by their own species or genera, known as characteristic fossils of these formations.

4. Characteristic fossils are those which occur most constantly in definite formations, and which as a rule do not extend their range above or below a definite geological horizon or platform. These characteristic fossils are not always the most numerous.

As research work on stratification developed it became necessary to divide those stratified rocks into groups and systems. This classification is arranged more in accordance with fossil remains contained in the various deposits than the lithological structure of the rocks.

The following scheme is generally approved for the classification of fossiliferous strata in descending order :—

Groups	Systems
1. Quaternary or Post Tertiary	Recent or Post Glacial Neolithic. Pleistocene or Glacial Palæolithic.
2. Tertiary or Kainozoic . .	Pliocene. Miocene. Oligocene. Eocene.
3. Secondary or Mesozoic . .	Cretaceous. Jurassic. Triassic.
4. Primary or Palæozoic . .	Permian. Carboniferous. Devonian or Old Red Sandstone. Silurian. Ordovician. Cambrian.
5. Archean or Precambrian.	

Kainozoic—from the Greek *kainos*, recent, +*zoe*, life—containing recent forms of life.

Mesozoic—from the Greek *mesos*, middle, +*zoe*, life—containing forms of life between recent and ancient.

Palæozoic—from the Greek *palaios*, ancient, +*zoe*, life—containing the oldest or ancient forms of life.

Neolithic—from the Greek *neos*, new, +*lithos*, a stone—the recent or new stone period.

Palæolithic—from the Greek *palaios*, ancient, +*lithos*, a stone —the ancient or old stone period.

Pleistocene—from the Greek *pleistos*, most, +*kainos*, recent—the system next the recent, but not included in it—in the Quaternary group.

Pliocene—from the Greek *pleion*, more, +*kainos*, recent—the more recent system of the Tertiary proper.

Miocene—from the Greek *meion*, less, +*kainos*, recent—the less recent of the Tertiary group.

Oligocene—from the Greek *oligos*, little, +*kainos*, recent—a little more recent than Eocene, and a little less recent than Miocene.

Eocene—from the Greek *eos*, dawn, +*kainos*, recent—the dawn or the beginning of the Tertiary or Kainozoic group.

Cretaceous—from the Latin *creta*, chalk—in reference to the large deposits of chalk during this period.

Jurassic—from the place-name *Jura*—in reference to the predominance of rocks of this age in the Jura mountains.

Triassic—from the Greek *trias*, three, +*ic*—in reference to its three well-marked sub-divisions in Germany.

Permian—from the place-name *Perm*—a term applied by Murchison to rocks described by him in the region of Perm, Russia.

Carboniferous—from the Latin *carbo-(n)*, coal, +*ferre*, to bear or carry—in reference to the formations containing or yielding coal or carbon.

Devonian—from *Devonia*—the Latinised form of Devon.

Silurian—applied by Murchison to a series of rocks worked out by him in that part of England and Wales formerly inhabited by the *Silures*.

Ordovician—so named by Lapworth from the *Ordovices*, an ancient British tribe who inhabited North Wales.

Cambrian—from the old name *Cambria*, Wales.

We shall now consider the various groups and systems in regard to their Palæontology or fossil remains, and we shall work upwards from the oldest or Archean rocks to the recent or Quaternary.

I. Archean System

The largest area of Archean rocks in this country lies along the western coast of Sutherland and Ross, and includes almost the whole of the Outer Hebrides.

These rocks consist of three different types, viz. :—

1. *Gneiss*—consisting chiefly of metamorphosed plutonic masses.
2. *Volcanic rocks*—composed chiefly of tuffs and lavas which have been more or less altered.
3. *Sedimentary rocks*—consisting of arkoses, grits, and shales.

Up to the present time no fossils have been found in these rocks, though in some of the upper shale deposits black, phosphatic markings occur which may indicate the presence of organic material, but no definite organic remains so far have been detected.

II. Cambrian System

The Cambrian beds in Britain occur generally in the same areas as the Archean. The outcrop in Scotland is in the North-West Highlands, and lies between the Archean rocks on the west already referred to and the Moine schists of the Highlands on the east. The exposure is not extensive and runs in a narrow strip from Loch Eireboll in the north to Skye in the south.

Speaking generally, the Cambrian deposits in Britain consist chiefly of sandstones and shales, with secondary formations of quartzites and slates. In the north there are large deposits of dolomitic limestone with bands of chert—the Durness limestone—which compose the upper parts of this system. The middle series of deposits contain limestones, quartzites, and grits. The lower strata are principally arenaceous or sandy—sandstones, grits, and quartzites. In these worm casts and burrows are found. The burrows, pipes, or tubes are now filled with white deposits of silica. The term 'Pipe Rock' is sometimes applied to this deposit in reference to this pipe-like structure.

Although the Cambrian system is the earliest to produce organic remains, yet in many instances the animal forms it contains are highly specialised, and it must have taken long ages in the process of evolution to develop such differentiated organisms. The most important animal fossils in this system are brachiopods and trilobites, but almost all the main branches of the inverte-

brate animal kingdom are represented, and they are probably all marine.

The Cambrian rocks are generally classified in three series according to the characteristic fossils found in the various deposits, viz. :—

1. *Olenus series*—where the genus *Olenus* is the characteristic fossil, and found in the upper formations.

2. *Paradoxides series*—from the genus *Paradoxides*, characteristic of the middle deposits.

3. *Olenellus series* –from the genus *Olenellus*, found at the base.

Olenus, *Paradoxides*, and *Olenellus* all belong to the Trilobite class (Crustacea).

Trilobite—from the Greek *treis* (*tri*), three, +*lobos*, a lobe, +*ite*—in reference to the body being divided into three lobes by means of two depressions or furrows, which extend from the anterior to the posterior extremity.

The following specimens represent this system.

(1) **Pipe Rock.** This rock is at present the oldest formation to show clear traces of animal life. Annelids dug deeply into the sands and left their burrows open. The sands in time became cemented with siliceous material forming quartzite rocks, and the burrows got filled up with white deposits of silica which give to the rock a peculiar spotted appearance on section.

(2) **Pipe Rock.** A pale grey quartzite rock with brownish iron staining on the surface. The rock is much weathered, and on the surface there are many roundish projections, the ends of the silica deposits which fill the pipes or burrows in the rock. The rock weathers quicker than the silica deposits, hence the projections.

(3) **Fossil —Trilobite.** On a piece of black shaly deposit there is a beautiful cast of a trilobite showing plainly the three lobes of the body. The head shield is broken.

A trilobite has a somewhat oval and flattened outline. It is divided into transverse segments, and consists of a head, thorax, and abdomen. The segments of the head are fused together and also those of the abdomen, but the segments of the thorax remain free. The dorsal surface is protected by a hard, phosphatic, calcareous outer covering or skeleton, and the part that covers the head is known

as the head shield. The ventral surface is covered by an uncalcified cuticle which is strengthened by transverse arches. Each segment of the body, except the last, carries a pair of appendages, which, with the exception of the first segment, are made up of two branches or parts—they are biramous. The first segment carries the antennules or feelers.

III. Ordovician System—sometimes termed Lower Silurian

In Britain the Ordovician deposits are more plentiful than the Cambrian and cover a wider area. In different areas different types of deposit or facies are generally recognised, viz. :—

1. *A shelly facies*—deposited in more or less shallow water with a somewhat coarse sedimentary deposit resulting in the formation of coarse slates, sandstones, and bands of nodular limestone.

The dominant fossils in this facies are brachiopods and trilobites, with corals and cystideans in the calcareous bands, and gastropods and lamellibranchs in the more sandy beds.

2. *A graptolitic facies*—deposited in deep water with fine sediment, ultimately forming slates or shales with bands of chert.

Graptolites are the common fossils in this deposit, with radiolarians in the chert.

3. *A volcanic facies*—the rocks consisting chiefly of lava flows, tuffs, and agglomerates usually deposited on the ocean floor, since sometimes they are interstratified with the shelly or graptolitic deposits.

The Ordovician and Silurian rocks, which are frequently grouped together as the Silurian system, compose the greater part of the Southern Uplands of Scotland. They run in a south-west direction across country from the east to the west coast, and geologically are generally divided into three more or less parallel bands or belts. The Ordovician or Lower Silurian deposits predominate in the Northern belt; the Llandovery and Tarannon are the chief components of the Middle belt; and the Upper Silurian deposits, composed chiefly of the Wenlock and Ludlow series, occupy the Southern belt. Owing to crustal movements the various strata are sometimes crumpled, distorted, and displaced in regard to their chronological order.

In the Ordovician system the fossil remains are similar to those

of the Cambrian, but the genera, species, and varieties are all increased in numbers. The dominating groups are brachiopods, trilobites, and graptolites. The greatest number of graptolitic genera belong to the Ordovician system, and they are generally either branched and uniserial, or single and biserial in habit. Corals and cystideans are also common, and gastropods and lamellibranchs are sometimes abundant.

Graptolite—from the Greek *graptos,* marked or written, +*lithos,* a stone—in reference to the markings resembling writing or pencil marks. Tarannon, Caradoc, Llandeilo, Ludlow, etc., are place names after which the various rocks or series of rocks are named.

Brachiopods—a phylum or group of animals closely resembling molluscs.

Gastropod, Lamellibranch, and Cephalopod—three classes of the phylum Mollusca.

In classifying the deposits of the Ordovician system, trilobites are the agents chiefly used in the shelly facies and graptolites in the graptolitic facies, and when interstratification occurs both agents are employed. As a rule Ordovician deposits are classified in three series according to the characteristic fossils which they contain. From below upwards they are—

(1) *Arenig series*; (2) *Llandeilo series*; (3) *Bala* or *Caradoc series.*

A graptolite is a plant-like colony of animals consisting of a stem with a canal or hollow in it, and bud-like projections on one or both sides of the stem. These buds communicate with the stem canal and they open externally by small apertures or mouths. The stem and buds together form the skeleton or polypary—from the Greek *polypous,* a polyp, +*ary*—covering which protects the animal. The bud-like processes are termed thecæ—from the Greek *theke,* a case or sheath—and are the compartments or sheaths in which the animals lived. The stem may be single or branched, and this condition, together with the arrangement of thecæ or buds, helps to determine the genus of the order.

The term stipe is generally used instead of branch. The following specimens are found in the Ordovician formations :—

(1) Graptolite. Gen. *Didymograptus.*

The polypary or skeleton is bilaterally symmetrical, consisting of two uniserial stipes or branches. The thecæ are subcylindrical in form and are in contact for part of their length.

(2) **Graptolite.** Gen. *Dicellograptus.*

Polypary is bilaterally symmetrical, the stipes are uniserial, the thecæ are tubular in form and somewhat curved (sigmoid).

(3) **Graptolite.** Gen. *Dicellograptus.*

(4) **Graptolite.** Gen. *Dicellograptus*, sp. *elegans.*

(5) **Graptolite.** Gen. *Climacograptus.*

Polypary is biserial, the thecæ are tubular with sigmoid curves, and the apertures or mouths are placed in depressions.

(6) **Graptolite.** Gen. *Climacograptus.* Two specimens on the tray.

(7) **Graptolite.** Gen. *Climacograptus*, sp. *scalaris.*

(8) **Graptolite.** Gen. *Diplograptus.*

Polypary biserial, thecæ sub-cylindrical, tubes overlapping and placed obliquely.

(9) **Graptolite.** Gen. *Diplograptus.*

(10) **Graptolite.** Gen. *Diplograptus*, sp. *truncatus.*

(11) **Graptolite.** Gen. *Diplograptus*, sp. *truncatus.*

(12) **Graptolite.** Gen. *Diplograptus.*

(13) **Graptolite.** Gen. *Diplograptus.*

(14) **Graptolite.** Gen. *Nemagraptus.*

Polypary bilaterally symmetrical, uniserial, consisting of two slender main stipes coming off the middle of a well-defined sicula with secondary branches. The thecæ are long tubes with sigmoid curvature. The sicula is a small conical body at the proximal end of the polypary where the earliest stage in the development of the graptolite begins.

(15) **Trilobite.** Gen. *Ogygia*, sp. *buchi.*

On a slaty deposit there is the cast of a trilobite. The left side shows well-defined central and lateral lobes and parts of the head shield. The right side is broken through the lateral lobe.

(16) **Trilobite.** Gen. *Ogygia*—similar to No. 15.

(17) **Trilobite.** Gen. *Ogygia*—similar to No. 15.

IV. Silurian System—sometimes termed Upper Silurian

In Britain the outcrops of Silurian rocks are numerous, and they have already been referred to in their distribution in the Southern Uplands of Scotland.

For geological purposes the Silurian system, like the Ordovician system, is generally divided into three series, characterised more or less definitely by their peculiar fossil remains. From below upwards the three series are as follows :—

1. *Valentian* {Llandovery. Tarannon. 2. *Salopian* {Wenlock. Ludlow. 3. *Downtonian.*

The general features of the organic remains found in the Silurian system are similar to those occurring in the Ordovician. As a rule the graptolites are uniserial. Many of the genera and species are distinct from the Ordovician forms, though some of the Ordovician genera are found in the Valentian series.

Corals and crinoids are abundant, but cystideans are less numerous than in the Ordovician deposits. Brachiopods and trilobites are plentiful, and there are abundant remains of gastropods, lamellibranchs, and cephalopods.

The earliest fossils of vertebrate animals, in the form of bones and spines of fishes, are found in the upper deposits of this system, and echinoids or sea urchins are preserved in the same deposits. Also in the same Salopian formations the last remains of the graptolites are met with, and the first fossil scorpion makes its appearance. This upper facies is chiefly distinguished by the fossil remains of Eurypterids.

The following specimens in the collection occur in the Silurian system :—

(1) **Graptolite.** Gen. *Retiolites.*

Polypary biserial and straight. Thecæ subprismatic or subcylindrical, tubes overlapping and placed obliquely. The wall or periderm consists chiefly of a network of threads and rods.

(2) **Graptolite.** Gen. *Monograptus.*

Polypary unbranched, uniserial and straight, curved or spiral. Thecæ vary in form in different species, and the sicula is attached to the proximal end of the polypary.

(3) **Graptolite.** Gen. *Monograptus,* sp. *sedgwickii.*

Several specimens on this tray—from Caddon Lee.

(4) **Graptolite.** Gen. *Monograptus,* sp. *priodon.*

(5) **Graptolite.** Gen. *Monograptus,* sp. *priodon.*

(6) **Graptolite.** Gen. *Monograptus,* sp. *priodon.*

(7) **Graptolite.** Gen. *Monograptus,* sp. *lobiferus.*

(8) **Graptolite.** Gen. *Monograptus,* sp. *exiguus.*

(9) **Graptolite.** Gen. *Rastrites.*

Polypary unbranched, uniserial, and straight, curved, or spiral. The thecæ are long, tubular, and widely separated. Three specimens on this tray.

(10) **Fossiliferous Rock.** This rock contains brachiopods of the Genus *Orthis* (*sensu lato*).

Brachiopod—from the Greek *brachion*, an arm, +*pous* (*pod-*), a foot—so named from two long processes given off from the sides of the mouth and known as arms. At first they were thought to serve as feet in locomotion.

(11) **Specimen** of shale showing annelide tracings.

(12) **Coral Fossil.** Gen. *Heliolites* one of the Anthozoa.

The corallum or entire skeleton is compound and formed of tubes of two sizes. The larger circular tubes are corallites or individual corals, and between them there are smaller polygonal tubes formed in material secreted by the common connecting portion of the colony termed the cœnosarc.

Cœnosarc—from the Greek *koinos*, common, +*sarkos*, flesh.

V. Devonian System

(*Old Red Sandstone in Scotland*)

The sedimentary deposits of the systems hitherto considered are all marine deposits, but in the Devonian system the formations have been laid down partly in the ocean and partly in lakes or land-locked seas.

During this geological period great changes took place in Northern Europe. The Silurian ocean-bed was raised above water, and in places enclosed lakes or inland seas. South of the Bristol Channel the changes were less marked, and the Silurian formations retained their position as the floor of probably a shallower sea.

This crustal movement produced two different types of deposits. In Devon and Cornwall the formations are marine, consisting of dull sandstones, slates, and limestones, which contain the remains of trilobites, brachiopods, corals, and other marine organisms. They do not differ markedly from those found in the Silurian rocks. To the north of the Bristol Channel the deposits are different. They consist chiefly of bright-coloured, red and brown sandstones and marls, but neither trilobites, brachiopods, nor corals are found in these strata, and the most important fossils contained in them are plant remains and the large scales

of armoured fishes. The former or marine facies is termed the *Devonian* type, and the latter or lacustrine (lake) facies is usually known as the *Old Red Sandstone* type of the Devonian system.

For descriptive purposes the Devonian facies is generally divided into three series, viz. (1) *Lower Series*, (2) *Middle Series*, (3) *Upper Series*; and the Old Red Sandstone facies into two series, viz. (1) *Lower Series*, (2) *Upper Series*, according to the assemblage of fossils they contain.

Devonian type.—Many of the Silurian genera range into the Devonian deposits. Corals are plentiful and crinoids are common in the limestone formations. Brachiopods are abundant in limestone, shale, and grits. Molluscs are plentiful in some deposits, and cephalopods are important in classifying the different series. Trilobites are becoming decadent and fewer in number, and some of the fish remains peculiar to the Old Red Sandstone type are also found here.

Old Red Sandstone type.—In some deposits the remains of Eurypterids, fishes, and plants are plentiful, but as a rule in this type of deposit fossils are not very abundant. As sponges are not unknown, and as fossil corals are abundant in Devonian type deposits, perhaps the following short description of a sponge and a coral may be helpful in distinguishing the one from the other.

A sponge polyp may be described as a hollow sack or tube attached at one end and free at the other. The wall of this tube or sack is thin and is perforated by numerous small openings or pores—hence the group or phylum Porifera to which sponges belong. Through these pores or openings water passes into the tube or sack cavity termed the gastral cavity, and thence out by the free opening or mouth termed the osculum—the Latin name for 'little mouth.' The thin wall of this tube or gastral cavity is made up of two layers, viz. :—

1. An outer or dermal layer composed of flattened cells, with a layer of softer cells underneath. The function of this layer is protective, and it also secretes the skeleton or supporting material of the sponge.

2. An inner or gastral layer composed of a single layer of cells, and to each cell is attached a hair-like process called a "flagellum"—the Latin name for a whip. The function of the flagella is to keep the water, which comes through the pores, flowing onwards out through the open end or osculum. In this manner the tube-like sponge received its food and oxygen from

the current of water, and the waste products of nutrition are carried away.

The skeleton or supporting structure consists either of a fibrous material of a horny nature termed spongin, or of hard spicules of silica, or of both. Sometimes the tubes grow irregularly, producing outgrowths and folds. These outgrowths and folds get fused together to form the much-thickened wall of a sponge, which contains spaces or channels between some of the folds and outgrowths through which water slowly flows.

Corals are grouped in the class Anthozoa, which also includes sea anemones.

Anthozoa —from the Greek *anthos*, a flower, +*zoon*, an animal —a flower-like animal.

A coral polyp in some respects resembles a sponge polyp, but it is more highly developed and it differs from a sponge in the following particulars : (1) It has no pores or openings in the body wall ; (2) It possesses an œsophageal tube or gullet, which opens into the body cavity or cœlenteron ; (3) It has the body cavity or cœlenteron divided into chambers or compartments.

The body wall of the coral is usually described as consisting of two layers of cells. The outer layer is termed the ectoderm or outside skin, which secretes the skeleton or calcareous material for supporting and protecting the polyp. The inner layer is termed the endoderm or inside skin, the cells of which are provided with hair-like processes or cilia. The cilia produce definite movements which induce a current of water in the body cavity. The mouth at the free end of the polyp is generally surrounded by elongated processes termed tentacles. The typical coral is cone-shaped and generally slightly curved, with one end fixed and the other end free. The unattached end is large and hollowed out, so as to form a depression termed the calyx. The sides and floor of the calyx carry a series of radiating ridges or septa which generally form the chief distinguishing features of corals. Corals may remain single or they may become compound and form colonies by budding and dividing. The entire hard skeleton secreted by the outer layer of the body wall is termed the corallum, and in colonies each individual skeleton is known as a corallite.

Cœlenteron—from the Greek *koilos*, hollow, +*enteron*, intestine. Corallium—the Latin name for Coral, from the Greek *korallion*.

The following fossils in the collection are grouped under the Devonian system :—

(1) **Coral.** Gen. *Heliolites*, sp. *porosa.* From Newton Abbot.

(2) **Coral.** Gen. *Heliolites*, sp. *porosa.* From Torquay.

(3) **Coral.** Gen. *Favosites*, sp. *cervicornis.* From Newton Abbot.

(4) **Coral.** Gen. *Favosites*, sp. *goldfussii.* From Torquay.

(5) **Coral.** Unpolished. Gen. *Favosites*, sp. *goldfussii.* From Torquay.

(6) **Specimen** of Old Red Sandstone with fossil markings of large scales of ganoid fishes.

Ganoid scales were thick, enamel-covered scales which articulated in such a manner as to form a coat of mail or armour. Ganoid —from the Greek *ganos*, brightness—in reference to the enamel-covered scales or plates found in certain fishes.

(7) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

(8) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

(9) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

(10) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

(11) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

(12) **Specimen** of Old Red Sandstone with fossil markings of ganoid scales.

The above specimens of fossil markings of ganoid scales are from Nairnshire.

(13) **Trilobite.** Gen. *Phacops*, sp. *lævis.*

The cast of a trilobite on a dark-coloured, fine-grained, slaty rock.

(14) **Trilobite.** Gen. *Phacops*, sp. *lævis.* Similar to No. 13.

(15) **Brachiopod.** From Newton, South Devon.

On this tray there are two specimens of brachiopods embedded in limestone.

(16) **Brachiopod.** From Newton, South Devon.

Four specimens of brachiopods on this tray embedded in limy deposit.

(17) **Brachiopod.** From Newton, South Devon.

Two specimens of brachiopods embedded in calcareous deposit.

(18) **Gastropod.** Gen. *Murchisonia* (*sensu lato*). From Chudleigh, South Devon.

The two specimens on this tray have turreted shells and more or less angular whorls.

Gastropod—from the Greek *gaster*, stomach, + *pous* (*pod-*), a foot—in reference to using the under surface of the body as an organ of locomotion on which to crawl or creep, as in the case of the snail.

The cephalopods are the most highly organised representatives of the phylum Mollusca, but as the soft parts of the animals are rarely preserved as fossils we have to consider chiefly the hard outer covering or shell as found in deposits of various geological periods.

Our exhibits of cephalopods in this collection are contained in the sub-orders Nautiloidea, Ammonoidea, and Decapoda. The nautiloids all possess an external shell which consists of a tube that tapers to a point at one end and is wide and open at the other. This shell-tube may be straight, curved, or spiral. In the spiral form the coils or whorls may be in contact throughout, partly free, or entirely separate. As a rule the coils are in one plane, but in some cases they are in the form of a helicoid or screw-like spiral. The shell-tube consists of many chambers separated from each other by transverse partitions or septa, and the chambers generally increase in size from the pointed end to the open aperture of the shell. The last chamber is usually large and is occupied by the animal, hence termed the body chamber. The shell grows by additions to the margin of the open end or aperture, and after a certain growth or enlargement the body of the animal moves forward and secretes a new septum behind it, so as to form another chamber. All the chambers except the last or body chamber are filled with air so as to give buoyancy to the shell. A slender tube-like prolongation of the dorsal end of the body, termed the siphuncle, connects all the chambers. The position of this siphuncle varies in different genera. In the nautilus it pierces the septa at or near the centres. The line where the septum joins the shell-cover is termed the suture, which may be simple or convoluted. In the Nautiloidea the suture is simple, straight, or slightly undulating, which is one of the characteristic features of this sub-order. Nautilus—from the Greek *nautilos*, a sailor—

in reference to the belief that it sailed by means of the expanded tentacular arms.

(19) **Cephalopod.** Gen. *Orthoceras.* From Petitor, Torquay.

A Cephalopod embedded in limestone. Note that the shell is straight and divided into compartments.

(20) **Cephalopod.** Gen. *Orthoceras.* From Petitor, Torquay.

This tray shows a calcareous deposit in which are embedded several beautiful cephalopods.

Cephalopod—from the Greek *kephale*, head, +*pous* (*pod-*), foot—having the organs of locomotion, called tentacles or arms, attached to the head.

(21) **Coral.** Gen. *Chonophyllum*, sp. *perfoliatum.* From Ramsleigh, Newton Abbot.

(22) **Coral.** Gen. *Cystiphyllum*, sp. *vesiculosum.* From Bradly Woods, Newton Abbot.

There are two specimens of coral on this tray embedded in dark-coloured limestone.

(23) **Coral.** Gen. *Alveolites*, sp. *suborbicularis.* From Teignmouth, South Devon.

(24) **Coral.** Gen. *Cyathophyllum*, sp. *obtortum.* Longitudinal section. From Bradly Woods, Newton Abbot.

(25) **Coral.** Gen. *Cyathophyllum*, sp. *obtortum.* Transverse section. From Torquay.

(26) **Coral.** Gen. *Acervularia*, sp. *pentagona.* From Ramsleigh, Newton Abbot.

(27) **Coral.** Gen. *Amplexus*, sp. *tortuosus.* From Newton, South Devon.

The following specimens belong to the class Hydrozoa and are termed Stromatoporoids—from the Greek *stroma*, a covering, +*poros*, a pore.

They are not so highly developed as the Anthozoa or corals. The body cavity is not divided into compartments and there are no septa. They secrete a calcareous skeleton, which is variable in form and consists of a series of concentric laminæ separated by spaces through which rod-like supports or pillars pass. This structure may grow to a considerable size.

(28) **Stromatoporoid.** Gen. *Stromatopora.* From Paignton, South Devon.

(29) **Stromatoporoid.** Gen. *Stromatopora.* From Petitor, Torquay.

(30) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Bradly Woods, Newton Abbot.

(31) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Bradly Woods, Newton Abbot.

Case 8

(32) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Lummaton, Torquay.

(33) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Newton, South Devon.

A shell is embedded in this specimen.

(34) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Torquay.

(35) **Stromatoporoid.** Gen. *Stromatopora*, sp. *concentrica.* From Torquay.

The remaining exhibits belong to the class Anthozoa, viz. :—

(36) **Coral.** Gen. *Cystiphyllum*, sp. *vesiculosum.* From Torquay.

(37) **Coral.** Gen. *Cyathophyllum*, sp. *cæspitosum*—small variety. Devonian coral from Torquay.

(38) **Coral.** Gen. *Favosites*, sp. *cervicornis.* Devonian coral from Ogwell, South Devon.

(39) **Coral.** Gen. *Smithia*, sp. *hennahi.* Devonian coral from Torquay.

(40) **Coral.** Gen. *Acervularia*, sp. *pentagona.* From Ramsleigh, Newton Abbot, South Devon.

(41) **Coral.** Gen. *Chonophyllum*, sp. *perfoliatum*—oblique section. From Newton, South Devon.

(42) **Coral.** Gen. *Cyathophyllum*, sp. *cæspitosum*—large variety. From Petitor, Torquay.

(43) **Coral.** Gen. *Cyathophyllum*, sp. *helianthoides.* Unpolished coral from Totnes, Torquay.

(44) **Coral.** Gen. *Acervularia*, sp. *intercellulosa.* From Wolborough, Newton Abbot.

(45) **Coral.** Gen. *Endophyllum*, sp. *bowerbanki.* From Petitor, Torquay.

(46) **Coral.** Gen. *Endophyllum*, sp. *abditum.* From Petitor, Torquay.

(47) **Coral.** Gen. *Alveolites*, sp. *compressa.* From Torquay.

(48) **Coral.** Gen. *Chonophyllum*, sp. *perfoliatum*—oblique section. Devonian coral from Newton, South Devon.

(49) **Coral.** From Lake Huron.

Two specimens of cup coral.

(50) **Plant Remains.** From Aberdeenshire.

Two specimens of Rhynie chert embedded in which are some well-preserved fossil plants.

VI. Carboniferous System

Like the formations of the Devonian system, the deposits of the Carboniferous system differ considerably in various regions, but there are two facies or types of deposit which have a wide distribution and which require to be mentioned here, viz. :—

1. *Marine type.* Limestone is in England the dominant deposit in this type and it is composed chiefly of the remains of encrinites, corals, molluscs, and other marine organisms.

2. *Lacustrine or Lagoon type.* Sandstones are of common occurrence. The strata vary in fineness of grain from mud to pebbly grits ; and dark-coloured shales containing carbonaceous matter, and sometimes ferruginous concretions, occur in seams or bands. Among these strata coal deposits in the form of seams are found. These coal seams, which vary in thickness and extent, form the Coal Measures of the Carboniferous system. The principal fossils in this deposit are plants and fresh-water lamellibranchs.

Between the two different facies or types there are deposits of coarse sandstones or grits, usually termed the Millstone Grit, with finer sand deposits and shales. Occasionally there are layers of limestone containing fossils. Fossils in the Millstone Grit are few and, as a rule, badly preserved, but they show that the plant remains belong to the Coal Measures Series, and that the limestone fossils are marine and associated with the fossil remains found in the Carboniferous limestone below.

Speaking generally, therefore, the Carboniferous system may be divided into three series from below upwards as follows :—

1. *Carboniferous Limestone Series*, or Lower Carboniferous, which is of marine type in England.

2. *Millstone Grit Series.*

3. *The Coal Measures Series*, or Upper Carboniferous, which is of lacustrine or lagoon type.

Corals, crinoids, brachiopods, lamellibranchs, gastropods, and cephalopods are met with abundantly in the Carboniferous limestone or lower series of this system. Some of the cephalopods are straight in form. The last of the trilobites are found in this formation and they never appear again. Fish remains are now common. Teeth, spines, and platy scales of ganoids and other fishes are often well preserved. For the first time amphibian fossils occur in the Lower Carboniferous deposits. In the Upper Carboniferous or Coal Measures Series plants and fresh-water lamellibranchs are the principal organic remains.

Lycopods, Equisetums, and 'Ferns' are the commonest and most widely distributed of the plants, and they supply a large proportion of the material of which the coal seams are composed.

The following are the principal differences in the four great classes of shells :—

A Brachiopod is a soft, mollusc-like animal protected by two valves or shells. The anterior is termed the ventral, and the posterior the dorsal valve. The ventral is nearly always larger than the dorsal and they both end in a beak or umbo. The ventral umbo is more prominent than the dorsal umbo, and generally has an opening at the apex or just beneath it. As a rule the shells of brachiopods are equilateral—that is, a line drawn from the umbo to the opposite edge or margin divides the shells into equal or similar parts. This fact, together with the difference in size between the two valves, and the opening at the umbo or beak, is sufficient to distinguish the shell of a brachiopod from that of a lamellibranch.

A Lamellibranch is a bivalve animal—a mollusc. The valves are placed laterally in regard to the body of the animal and not antro-posteriorly. The two valves are joined together by means of a hinge and ligament along the dorsal margin. Speaking generally, the two valves are equal in size or nearly equal in size, and as a rule the valves are inequilateral—that is, when a line is drawn from the umbo or beak to the opposite free margin, the shell is divided into two unequal parts.

Lamellibranchs—from the Latin *lamella*, a plate, +*branchiæ*, gills—in reference to the broad or plate-like gills of the animal.

Most gastropods on the other hand have shells in one piece —hence termed univalve. In most cases the shell is tube-like, open at one end, tapering to a point at the other, and coiled into

a screw-like spiral, the coils of which are termed whorls. Again, the shell may be hollow and cone-like, but the shell and whorls vary in different genera and species.

A Cephalopod is also an example of a univalve shell. The shell is in one piece and divided into a number of chambers or compartments—see description given above, p. 185.

The following fossils belong to the Carboniferous system :—

(1) **Coral.** Gen. *Cyathophyllum.* Two specimens of a cup coral, so called from their resemblance to drinking horns or cups.

(2) **Coral.** Gen. *Clisiophyllum.* Two more specimens of a cup coral.

(3) **Coral.** Gen. *Zaphrentis.* Cup corals of various sizes. The septa are well marked in the largest specimen.

(4) **Coral.** Gen. *Lithostrotion*, sp. *junceum.*

(5) **Coral.** Gen. *Lithostrotion*, sp. *junceum.*

(6) **Crinoids.** Gen. *Poteriocrinus.* Several specimens of various sizes.

(7) **Crustacean.** Sub-order Mysidacea, Gen. *Anthrapalæmon*, sp. *etheridgii.*

(8) **Crustacean.** Sub-order Mysidacea, Gen. *Pseudogalathea*, sp. *macconochii.*

(9) **Brachiopod.** Gen. *Spirifer.* A number of specimens of various sizes.

(10) **Brachiopod.** Gen. *Spirifer*, sp. *striatus*, var. *princeps.*

(11) **Brachiopod.** Gen. *Orthis* (*sensu lato*). Several specimens on this tray which vary in size.

(12) **Brachiopod.** Gen. *Athyris.* Several specimens.

(13) **Brachiopod.** Gen. *Productus.* Three specimens.

(14) **Brachiopod.** Gen. *Productus*, sp. *latissimus.*

(15) **Brachiopod.** Gen. *Productus*, sp. *giganteus.*

(16) **Brachiopod.** Gen. *Productus*, sp. *giganteus.*

(17) **Brachiopod.** Gen. *Productus.* Four specimens.

(18) **Brachiopod.** Gen. *Productus*, sp. *punctatus.* Two specimens.

(19) **Brachiopod.** Gen. *Productus*, sp. *scabriculus.* Three specimens.

(20) **Brachiopod.** Gen. *Schizophoria*, sp. *resupinata.* Two specimens.

(21) **Lamellibranch.** Gen. *Edmondia*, sp. *sulcata.* Four specimens.

(22) **Lamellibranch.** Gen. *Carbonicola.*

(23) **Lamellibranch.** Gen. *Sanguinolites.*

(24) **Lamellibranch.** Gen. *Aviculopecten*, sp. *dissimilis.*

(25) **Lamellibranch.** Gen. *Aviculopecten*, sp. *dissimilis.*

(26) **Fossiliferous Rock.** Embedded in the matrix are numerous specimens of the genus *Modiola.*

(27) **Fossiliferous Rock.** Embedded in the matrix are numerous specimens of the genus *Myalina.*

(28) **Gastropod.** Gen. *Euomphalus.*

(29) **Gastropod.** Gen. *Euomphalus.*

(30) **Gastropod.** Gen. *Euomphalus*, sp. *pentangulatus.* Two specimens.

(31) **Gastropod.** Gen. *Loxonema.* Three specimens.

(32) **Gastropod.** Gen. *Naticopsis.*

(33) **Gastropod.** Gen. *Bellerophon.*

(34) **Cephalopod.** Gen. *Orthoceras.*

Fossil Plants

Stigmaria. This fossil is now recognised as the root parts of the Lycopods—Sigillaria and Lepidodendron.

It is generally found in long, compressed, or rounded fragments, the surfaces of which are covered with roundish pits, each having a small pit in the centre from which the cylindrical rootlets grew.

Stigmaria—from the Greek *stigma*, a mark, +*aria.*

(35) **Lycopodiales—Stigmaria**
(36) **Lycopodiales—Stigmaria**
(37) **Lycopodiales—Stigmaria**
The root parts of Sigillaria and Lepidodendron.

Lycopod—from the Greek *lykos*, a wolf+*pous* (*podos*), a foot —so named from the appearance of the root.

Case 9

Calamites. The stems of the Calamites were hollow, or a core of pith only, and are generally represented by internal casts.

These casts have vertical flutings, alternating in position at the nodes where whorls of leaves or branches grew.

Calamites—from the Greek *kalamos*, Latin *calamus*, a reed.

Equisetales—from the Latin *equus*, a horse, +*seta*, a bristle—horse tail or bristle.

(38) **Equisetales.** Gen. *Calamites.*

(39) **Equisetales.** Gen. *Calamites.*

(40) **Equisetales.** Gen. *Calamites.*

Lepidodendron. The Lepidodendra were tree-like plants which attained their maximum in the Carboniferous period. The trunks of the larger species branched in a bifurcating manner, and the bark was marked with numerous rhombic or oval scars, indicating the points where the needle-shaped leaves were formerly attached.

Lepidodendron—from the Greek *lepis* (*lepid-*), a scale, +*dendron*, a tree—in reference to the scale-like markings.

(41) **Lycopodiales.** Gen. *Lepidodendron.*

(42) **Lycopodiales.** Gen. *Lepidodendron.*

(43) **Lycopodiales.** Gen. *Lepidodendron.*

Sigillaria. Like the Lepidodendra the Sigillariae were plentifully represented in, and were characteristic of, the Carboniferous forests. The trunks had longitudinal ridges with vertical alternating rows of oval leaf-scars, the points where the leaves were originally attached.

Sigillaria—from the Latin *sigilla*, a seal—in reference to the seal-like scars.

(44) **Lycopodiales.** Gen. *Sigillaria.*

(45) **Lycopodiales.** Gen. *Sigillaria.*

Ferns and fern-like plants were plentifully represented in the Carboniferous period. They are frequently found in the Coal Measures, and the species include both the herbaceous and the arborescent forms.

(46) **Filicales.** Gen. *Pecopteris* perhaps in this class.

(47) **Pteridospermeæ.** Gen. *Sphenopteris.*

(48) **Pteridospermeæ.** Gen. *Neuropteris.*

(49) **Pteridospermeæ.** Gen. *Neuropteris.*

Filicales—from the Latin *filix* (*filic-*), a fern+*al.*

Pteridospermeæ—from the Greek *pteris* (*pterid-*), a kind of fern+*sperma*, seed—a fern that bears seed.

Fishes. The remains of many genera and species of fishes are found in the Carboniferous deposits of Scotland.

(50) **Fish.** Gen. *Amblypterus*, sp. *beaumonti.*

(51) **Fish.** Gen. *Amblypterus*, sp. *beaumonti.*

(52) **Fish.** Gen. *Amblypterus.* From a coal mine, Midlothian.

(53) **Fish.** Gen. *Rhadinichthys.*

(54) **Fish.** Gen. *Amblypterus*, sp. *angustus.*

(55) **Fish.** Gen. *Elonichthys.*

VII. Permian System

The geographical area of Europe during the Permian period was not unlike the Europe of the Devonian epoch. There was a continent in the North and West, while the South and East formed part of the ocean-bed.

In Northern Europe there were large land-locked seas, and the Permian deposits were laid down partly in those seas and partly on the surface of the land itself. The conditions were unfavourable to the fauna originally derived from the Carboniferous seas. Many of the genera became extinct, and those that survived were small and decadent in form. But there were exceptions to this general statement, and a few genera which apparently were able to suit themselves to the changing surroundings became vigorous in growth and plentiful in numbers, as in the case of the Polyzoa and some others.

In Scotland a series of red sandstones—breccias and conglomerates—crop out in Ayrshire, Dumfriesshire, Loch Ryan in Wigtownshire, and in the Isle of Arran, which rest uncomfortably on older rocks. No fossils have been found in them, their age is uncertain, and sometimes they are referred to the Permian and sometimes to the Trias.

In the Permian deposits in Germany the earliest remains of reptiles are found, and the bones and foot-prints of labyrinthodonts are not uncommon.

Labyrinthodonts—from the Greek *labyrinthos*, a labyrinth, +*odous* (*odont-*), a tooth—in reference to the complicated microscopic structure of the teeth. In some of the Permian deposits fossil fishes are relatively abundant.

CHAPTER XIV

Mesozoic Group. Cases 9 and 10

I. Trias or Triassic System

The British Triassic formations were laid down on the rough surface of a continent where the deposits gradually filled up the hollows. Since the British Trias was a continental deposit, much of the material accumulated beneath terrestrial waters. The occurrence of rock salt and gypsum clearly prove the presence of salt lakes, and the lower Trias contains water-worn pebbles.

The English Trias deposits are generally divided into three principal groups, viz. :—

1. *The Rhœtic* or upper group—consisting of a band of grey and black marls with marine fossils. Rhætic—from the place-name *Rhœtia*, in the East Alpine region.

2. *Keuper* or middle group—consisting of red sands and marls with layers of rock salt and gypsum. Keuper—the German name for this group—a local miners' term.

3. *Bunter* or lower group—which consists of red and variegated sandstones with pebble beds. Bunter—the German name for the group—from *bunt*, variegated or many coloured.

The most interesting of the Scottish Triassic rocks are the Elgin sandstones, which are found on the coast near Lossiemouth. They have yielded a remarkable series of reptilian remains.

Speaking generally, owing to the paucity of marine deposits, animal life is poorly represented in the English Triassic formations. Only in the Rhætic deposits are marine fossils found.

In other regions beyond Northern Europe the various forms of animal life are well represented, and the remains of fishes, labyrinthodonts, and reptiles are frequently found. In this catalogue the Triassic fossils are described along with those from the Jurassic.

II. Jurassic System

The rocks belonging to this system consist chiefly of clays and limestone, mostly of marine origin, though some of them are estuarine deposits.

This period is sometimes referred to as 'The age of Cycads,' 'The age of Ammonites,' 'The age of Reptiles,' according to the interests and the views of those engaged in the pursuit of natural science. These three names indicate the most imposing features in the flora and fauna.

Reptiles played a great part during this age. In the sea they were represented by the Ichthyopterygians and the Sauropterygians, on land by the Dinosaurians, and in the air there were the Pterosaurians.

Cycad—from the Greek name for a palm—meaning plants having affinity to ferns and resembling palms in their general appearance.

Ichthyopterygian—from the Greek *ichthys*, a fish, +*pterygion*, a wing or fin—an animal with a fish-like body and limbs in the form of fins.

Sauropterygian—from the Greek *sauros*, a lizard, +*pterygion*, a wing or fin—a lizard-like animal with fin-like limbs.

Dinosaurian—from the Greek *deinos*, great or mighty, +*sauros*, a lizard—a great or mighty lizard.

Pterosaurian—from the Greek *pteron*, a wing, +*sauros*, a lizard —a winged or flying lizard.

The earliest fossil remains of birds are found in the Jurassic deposits, and many mammals which lived in that period appear to have been marsupials.

This system is usually divided into two, viz. (1) The *Lias* or lower beds, (2) The *Oolitic* or upper beds, both of which are marine deposits.

The characteristic fossils of this period are the ammonites.

The first fossil specimen exhibited in the Mesozoic group is a crinoid.

Crinoids belong to the class Crinoidea and include sea-lilies and feather-stars.

The skeleton or test consists of three parts, viz. (1) *the Stem*; (2) *the Calyx*; (3) *the Arms*, given off from the upper surface of the calyx.

The stem varies in length and is made up of a number of segments termed columnals which may be disc-like, cylindrical, or pentagonal in form. The columnals are pierced in the centre by a canal which contains a prolongation of nervous and vascular structures. From the lower end of the stem sometimes small branches are given off, forming root-like extensions.

The calyx, which is situated at the upper end of the stem,

s globular or cup-shaped, and contains the digestive and other important organs. It consists of a series of plate-like structures arranged in such a manner as to form a cup-like hollow.

The arms—five in number—project from the plate-like structures at the top of the calyx termed ‘radials’ and are characteristic of the Crinoidea. They are formed either by a single or a double row of plate-like pieces termed ‘brachials,’ which are connected by muscles with which the movements of the arms are effected.

(1) **Crinoid.** Gen. *Encrinus.* From the Muschelkalk, Germany.

This specimen shows the calyx composed of plate-like structures, and the arms springing from the radials in the upper row of the calyx.

(2) **Anthozoan.** Derived Devonian coral found in the Trias near Torquay.

(3) **Coprolite.** The petrified excrement of an ichthyosaurian, or fish-like lizard, found in the Lias.

(4) **Fish.** The fossil bone of a fish.

(5) **Fish.** Vertebra of an ichthyosaurian. The vertebra is comparatively thin and both ends are markedly concave.

(6) **Fish.** The large spine of a ganoid fish with linear tubercles.

(7) **Fish.** The spine of a placoid fish—serrated.

(8) **Fish.** The spine of a placoid fish—serrated and ribbed.

(9) **Fish.** The large, broad tooth of a placoid fish.

(10) **Fish.** The large, conical tooth of a ganoid fish.

(11) **Fish.** The large, conical tooth of a ganoid fish.

(12) **Fish.** Teeth of a placoid fish.

Placoid from the Greek *plax*, a plate, +*idos*, form—in reference to the irregular bony plates, grains, or spines found in the skin of certain fishes.

(13) **Lamellibranch.** Gen. *Pecten.* From the Lias, Whitby.

(14) **Lamellibranch.** Gen. *Gryphœa,* sp. *incurva.*

(15) **Lamellibranch.** Gen. *Pinna.*

(16) **Lamellibranch.** Gen. *Pinna.*

(17) **Lamellibranch.** Gen. *Homomya.*

(18) **Lamellibranch.** Gen. *Pholadomya.* From the Middle Lias, Robin Hood’s Bay.

(19) **Gastropod.** Gen. *Pleurotomaria*, sp. *similis.* From the Lower Lias, Robin Hood's Bay.

(20) **Lamellibranch.** Gen. *Pecten*, sp. *demissus.* From Ventnor, Isle of Wight.

(21) **Lias Rock.** Polished. This specimen shows numerous sections of mollusc shells, chiefly lamellibranchs.

(22) **Lamellibranch.** Gen. *Ostrea.*

(23) **Cephalopod.** Gen. *Nautilus.*

(24) **Cephalopod.** Gen. *Nautilus.*

(25) **Cephalopod.** Gen. *Nautilus.*

(26) **Cephalopod.** Gen. *Nautilus.*

Ammonites form a large and varied group of cephalopods which belong to the sub-order Ammonoidea. As a rule the shell, which is multi-chambered, is in the form of a flat spiral with coils or whorls in contact, and frequently the sutures show complicated patterns. The siphuncle or tube which connects the chambers is generally placed on the dorsal or convex side of the shell, and the septa which separate the chambers are frequently folded or undulated in a complex manner, producing the suture patterns already referred to. The surface of the shell is sometimes smooth, but it is generally ornamented with striæ, ribs, tubercles, or spines. In some species a keel-like ridge, which may be smooth or toothed, runs along the outer or convex margin of the shell. Siphuncle—from the Latin *siphunculus*, a little tube.

The sutures and ornamentations vary much in form and, together with the arrangement of the coils, play a very important part in determining the numerous genera and species of ammonites.

Ammonite—from the *God Ammon—Cornu Ammonis*—the horn of Ammon. The Egyptian God Ammon, the God of Life, was represented as a human figure with a ram's head. The ram's head always had beautifully curved horns, hence the name from the resemblance of some of these cephalopods to Ammon's horn.

(27) **Ammonoids.** Two specimens cut longitudinally to show the coils and ridge markings of the shell.

(28) **Pebble—Lias.** This specimen shows ammonoids embedded in a pebble.

(29) **Ammonoid.** In this large specimen the outer shell has been removed to expose the beautiful and complicated suture markings.

(30) **Rock—Lias.** A mass of rock embedding numerous ammonoids, chiefly of the gen. *Gagaticeras*. From the Lower Lias, Robin Hood's Bay.

(31) **Rock—Lias.** A mass of rock embedding several ammonoids of the gen. *Harpoceras*. From the Upper Lias, Whitby.

(32) **Ammonoid.** This specimen is not very distinctly marked. It belongs to the species '*Ammonites*' *simpsoni*. From the Lower Lias, Robin Hood's Bay.

Case 10

(33) **Ammonoid.** Gen. *Phylloceras*, sp. *heterophyllum* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(34) **Ammonoid.** Gen. *Hildaites*, sp. *levisoni* (Simpson).
Locality—Whitby.
Stratigraphy—Upper Lias, Jet Rock.
Chronology—Harpoceratan, Hildaites.

(35) **Ammonoid.** Gen. *Hildoceras*, sp. *laticosta* Bellini.
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(36) **Ammonoid.** Gen. *Eleganticeras*, sp. *pseudo-elegans* S. Buckman.
Locality—Whitby.
Stratigraphy—Upper Lias, Jet Rock.
Chronology—Hildoceratan, Exaratum.

(37) **Ammonoid.** Gen. *Pararnioceras*, sp. *alcinoe* (Reynès).
Locality—doubtful.
Stratigraphy—Lower Lias.
Chronology—Microderoceratan, Alcinœ.

(38) **Ammonoid.** Gen. *Dactylioceras*, sp. *angulatum* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale, Bifrons Beds.
Chronology—Hildoceratan, Bifrons.

(39) **Ammonoid.** Gen. *Dactylioceras*, sp. *tenuicostatum* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Grey Shale.
Chronology—Harpoceratan, Tenuicostatum.

(40) **Ammonoid.** Gen. *Hildoceras*, sp. *hildense* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(41) **Ammonoid.** Gen. *Caloceras*, sp. *belcheri* (Simpson).
Locality—Whitby.
Stratigraphy—Lower Lias, Planorbis Beds.
Chronology—Psiloceratan, Johnstoni.

(42) **Ammonoid.** Gen. *Paltopleuroceras*, sp. *hawskerense* (Young and Bird).
Locality—Whitby.
Stratigraphy—Middle Lias.
Chronology—Amaltheian, Hawskerense.

(43) **Ammonoid.** Gen. *Dactylioceras*, sp. *tenuicostatum* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Grey Shale.
Chronology—Harpoceratan, Tenuicostatum.

(44) **Ammonoid.** Gen. *Porpoceras*, sp. aff. *bollense* (Zieten).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Crassoides.

(45) **Ammonoid.** Gen. *Harpoceras*, sp. aff. *exaratum* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Jet Rock.
Chronology—Harpoceratan, Exaratum.

(46) **Ammonoid.** Gen. *Dactylioceras*, sp. *commune* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(47) **Ammonoid.** Gen. *Dactylioceras*, sp. *commune* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(48) **Ammonoid.** Gen. *Asteroceras*, sp. *marstonense* Spath.
Locality—Robin Hood's Bay.
Stratigraphy—Lower Lias.
Chronology—Asteroceratan, Stellare.

(49) **Ammonoid.** Gen. *Seguenziceras*, sp. *nitescens* (Young and Bird).
Locality—Whitby.
Stratigraphy—Middle Lias.
Chronology—Amaltheian, Seguenziceras.

(50) **Ammonoid.** Gen. *Porpoceras*, sp. aff. *bollense* (Zieten).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Crassoides.

(51) **Ammonoid.** Gen. *Porpoceras*, sp. *verticosum* S. Buckman.
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale, Bifrons Beds.
Chronology—Hildoceratan, Crassoides.

(52) **Ammonoid.** Gen. *Arnioceras*, sp. aff. *notatum* Tucker and Trueman.
Locality—Whitby.
Stratigraphy—Lower Lias, Semicostatum Beds.

(53) **Ammonoid.** Gen. *Pseudolioceras*, sp. *lythense* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Braunianum.

(54) **Ammonoid.** Gen. *Harpoceras*, sp. *mulgravium* (Young and Bird).
Locality—Whitby.
Stratigraphy—Upper Lias, Serpentinus—Falcifer Beds.
Chronology—Harpoceratan, Falciferum.

(55) **Ammonoid.** Gen. *Peronoceras*, sp. aff. *annuliferum* (Simpson).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Fibulatum.

(56) **Ammonoid.** Gen. *Peronoceras*, sp. *fibulatum* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Fibulatum.

(57) **Ammonoid.** Gen. *Porpoceras*, sp. *vortex* (Simpson).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale, Bifrons Beds.
Chronology—Hildoceratan, Crassoides.

(58) **Ammonoid.** Gen. *Oxynoticeras*, sp. *lens* (Simpson).
Locality—Robin Hood's Bay, Whitby.
Stratigraphy—Lower Lias, Oxynotus Beds.
Chronology—Oxynotoceratan, Simpsoni.

(59) **Ammonoid.** Gen. *Arietites*, sp. *plotti* (Reynès).
Locality—Lyme Regis, Dorset.
Stratigraphy—Lower Lias, Birchi Beds.
Chronology—Microderoceratan, Plotti.

(60) **Ammonoid.** Gen. *Dactylioceras*, sp. *commune* (J. Sowerby).
Locality—Whitby.
Stratigraphy—Upper Lias, Alum Shale.
Chronology—Hildoceratan, Bifrons.

(61) **Ammonoid.** Gen. *Gagaticeras*, sp. *funiculatum* S. Buckman.
Locality—Robin Hood's Bay, Whitby.
Stratigraphy—Lower Lias, Oxynotus Beds.
Chronology—Oxynotoceratan, Gagateum.

(62) **Ammonoid.** Gen. *Eleganticeras*, sp. aff. *pseudo-elegans* S. Buckman.
Locality—Whitby.
Stratigraphy—Upper Lias, Jet Rock.
Chronology—Harpoceratan, Exaratum.

(63) **Ammonoid.** Gen. *Amaltheus*, sp. *subnodosus* (Young and Bird).
Locality—Whitby.
Stratigraphy—Middle Lias, Margaritatus Beds.
Chronology—Amaltheian, Margaritatus.

(64) **Ammonoid.** Gen. *Gagaticeras*, sp. *gagateum* (Young and Bird).
Locality—Robin Hood's Bay, Whitby.
Stratigraphy—Lower Lias, Oxynotus Beds.
Chronology—Oxynotoceratan, Gagateum.

(65) **Ammonoid.** Gen. *Psiloceras*, sp. *erugatum* (Bean and Phillips).
Locality—Whitby.
Stratigraphy—Lower Lias, Planorbis Beds.
Chronology—Psiloceratan, Erugatum.

(66) **Ammonoid.** Longitudinal section showing chambers and septa. Note the large body chamber, and the septa concave forwards.

Belemnites are cephalopods which belong to the sub-order Decapoda—from the Greek *deka*, ten, +*pous* (*pod*), a foot—in reference to the ten tentacles which project from the head and which are used in locomotion.

The soft parts of belemnites are not often preserved as fossils, and the following is a short description of the hard parts or shells which are usually found. The shell is made up of three portions, viz. :—

1. *The Guard.* This is a solid structure which varies in shape from cylindrical to conical and very often resembles a cigar in outline. The guard consists of a number of layers of minute prisms of calcite secreted round an axial line, producing a radiating appearance in transverse section. It is pointed at one end and blunt at the other, which contains a conical cavity or alveolus.

2. *The Phragmocone*—from the Greek *phragma*, a partition, +*konos*, a cone—in reference to this part containing the partitions or septa which form the chambers of the shell. This is the chambered portion of the shell and is conical in shape. Part of this cone fits into the hollow cone or alveolus in the blunt end of the guard. The chambers are formed by partitions or septa which are concave in front and are pierced by a marginal tube—the siphuncle—which connects the various chambers with one another.

3. *The Pro-ostracum*—from the Greek *pro*, before, +*ostracon*, a shell—in reference to the projection of this part of the shell. The front part of the wall of the phragmocone projects forward into a laminar or broad expansion which is termed the pro-ostracum, and behind this plate-like structure was the head of the belemnite.

The part of the belemnite most frequently found as a fossil is the guard—popularly known as the thunderbolt.

Belemnite—from the Greek *belemnon*, a dart or missile.

(67) **Cephalopod.** Gen. *Belemnites*, sp. *cylindricalis.* Three specimens, one of which is seen in longitudinal section, showing the guard and the phragmocone.

(68) **Cephalopod.** Gen. *Belemnites.* Three specimens. One specimen seen in longitudinal section, showing the position of guard and phragmocone.

(69) **Cephalopod.** Gen. *Belemnites*, sp. *dorsalis.* Two specimens.

(70) **Cephalopod.** Gen. *Belemnites.* Longitudinal section to show the chambered structure and the relation of the guard and phragmocone. Also note that the partitions are concave forwards.

(71) **Crinoid.** Gen. *Encrinus.*

(72) **Lamellibranch.** Gen. *Cardium.* From the Lower Lias, Stanton.

III. Cretaceous System

This system is generally described as consisting of Upper and Lower Cretaceous formations. These formations differ from one another in character and distribution.

1. The lower formations are chiefly sands and clays, partly fresh-water and partly marine in origin.

2. The upper formations are almost entirely marine, and consist chiefly of chalk with a variable deposit of clay and sand at the base.

The Lower Cretaceous is somewhat limited in extent and is over-laid by the Upper Cretaceous deposits which spread far beyond the margins of the lower formations. There was an increase in the sea area during the period of deposition of the Upper Cretaceous, and judging from the purity of the chalk there must have been little terrestrial detritus carried into the ocean depths.

The green sands and chalk deposits are the outstanding features of the Cretaceous system.

Ferns and cycads were the dominant plants, and sponges, echinoderms, brachiopods, molluscs, fishes, and reptiles were among the forms of animal life plentifully represented in this epoch.

The following fossils are from the Cretaceous formations :

(1) **Nautiloid.** Gen. *Nautilus*, sp. *plicatus.* From Ventnor.

(2) **Ammonoid.** A large, indistinctly marked Ammonoid from the Chalk Marl, Ventnor.

(3) **Ammonoid.** Gen. *Acanthoceras*, sp. *rothomagense.* From Ventnor.

(4) **Ammonoid.** Gen. *Calycoceras*, sp. *costatum* (Mantell).
Locality—Isle of Wight.
Stratigraphy—Chalk Marl, Lower Cenomanian.
Chronology—Schloenbachian, Naviculare.

(5) **Ammonoid.** Gen. *Acanthoceras*, sp. *sussexiense* (Mantell).
Locality—Isle of Wight.
Stratigraphy—Grey Chalk, Upper Cenomanian.
Chronology—Acanthoceratan, Cenomanense.

(6) **Ammonoid.** Gen. *Schloenbachia*, sp. *varians* (J. Sowerby).
Locality—Isle of Wight.
Stratigraphy—Grey Chalk, Lower Cenomanian.
Chronology—Schloenbachian, Costata.

(7) **Ammonoid.** Gen. *Schloenbachia*, sp. *coupei* (Brongniart).
Locality—Isle of Wight.
Stratigraphy—Grey Chalk, Lower Cenomanian.
Chronology—Schloenbachian, Costata.

(8) **Ammonoid.** Gen. *Parahoplitoides*, sp. *deshayesi* (Leymerie).
Locality—Isle of Wight.
Stratigraphy—Atherfield Clay, Lower Aptian.
Chronology—Parahoplitoidan, Weissi.

(9) **Ammonoid.** Gen. *Acanthoceras*, sp. *rothomagense* (Defrance).
Locality—Isle of Wight.
Stratigraphy—Grey Chalk, Upper Cenomanian.
Chronology—Acanthoceratan, Cenomanense.

(10) **Ammonoid.** Gen. *Amœboceras*, sp. *kitchini* (Salfeld).
Locality—Eathie, Sutherlandshire.
Stratigraphy—Lower Kimeridge.
Chronology—Perisphirectean.

(11) **Ammonoid.** Gen. *Aspidoceras*, sp. aff. *ægir* (Oppel).
Locality—Brora, Sutherlandshire.
Stratigraphy—Corallian, Argovian.
Chronology—Perisphirectean, Transversarius.

(12) **Anthozoan.** Coral. From the Chalk Marl, Ventnor.

(13) **Fossil Shells.** Various. Embedded in Greensand rock. From Isle of Wight.

(14) **Lamellibranch.** Gen. *Pecten*, sp. *beaveri*. From the Lower Chalk, Cambridgeshire.

(15) **Lamellibranch.** Gen. *Pecten*, sp. *asper*. From Upper Greensand, Ventnor.

(16) **Echinoid.** Gen. *Echinus*. From the Flint Deposit, Isle of Wight.

(17) **Lamellibranch.** Gen. *Spondylus*, sp. *spinosus*.

(18) **Brachiopod.** Gen. *Rhynchonella*, sp. *octoplicata.* From the Upper Greensand, Ventnor.

(19) **Lamellibranch.** Gen. *Gervillia*, sp. *anceps.* From Atherfield, Lower Greensand.

(20) **Lamellibranch.** Gen. *Panopœa.* From Lower Greensand, Sandown.

(21) **Gastropod.** Gen. *Paludina.* Fossils embedded in rock. From Wealden, Sandown.

(22) **Lamellibranch.** Gen. *Ostrea.* From Franklin, Isle of Wight.

Echinoderms. One of the characteristic features of the skeleton of an echinoderm is that it is composed of a series of units, each unit of which is in molecular constitution a crystal of calcite, though not in external form. These units vary in size and outline, and they have their distinctive names. Another common feature is the ‘ five-ray ’ symmetry of the shell. The skeleton of the echinoderm is not truly external, but is covered by a very thin, soft membrane, though it is generally spoken of as external.

Class Echinoidea. Echinoids or sea-urchins are usually globular, discoidal, or heart-shaped in form, and generally covered with spines. The shell or skeleton may be described as consisting of three parts, viz. (1) *the Apical Disc*, which is a small patch of plates situated at the summit or apex of the test or shell, (2) *the Corona*, which is the main part of the skeleton or test, (3) *the Peristome*, which occupies a position about the centre of the under surface opposite the apical disc, is that part which lies between the mouth and the lower part of the corona and which usually bears plates. The corona forms the main part of the skeleton or test, and consists of twenty columns of units termed plates, which extend from the apical disc to the peristome. There are two different kinds of plates forming the columns. One kind is termed the ambulacral plates. They are perforated by pores for the passage of the tube-like feet to the exterior, and they are grouped in double rows or columns. The other kind is termed the inter-ambulacral plates because they occupy the area or space between the double rows of ambulacral plates, and they too are grouped in double rows or columns. Both kinds of plates are angular at the inner ends, and alternate on each side in the columns so that the line of contact between the two columns is in zig-zag form. Each double row or column is termed an area, so

that there are five ambulacral and five inter-ambulacral areas. The ambulacral plates are smaller and more numerous than the inter-ambulacral plates, and each plate is pierced by two pores for the passage of the tube-like feet already referred to. All the plates of the corona—both ambulacral and inter-ambulacral—are provided with rounded projections termed tubercles, which vary in size and to which the spines or radioles of the echinoids are attached.

(23) **Echinoid.** Gen. *Echinus.* Two specimens from the Flint Deposit, Isle of Wight.

(24) **Echinoid.** Gen. *Micraster.* Two specimens from the Flint Deposit, Isle of Wight.

(25) **Crustacean.** Sub-order Decapoda. Gen. *Hoploparia.* From the Lower Greensand, Isle of Wight.

(26) **Lamellibranch.** Gen. *Plagiostoma.* From Isle of Wight.

(27) **Brachiopod.** Gen. *Terebratula.* From Atherfield, Lower Greensand.

(28) **Tooth—Fossil.** From placoid Fish. Gen. *Otodus*, sp. *appendiculatus.* From the Chalk Marl, Ventnor.

(29) **Lamellibranch.** Gen. *Thetis.* From Shanklin, Isle of Wight.

(30) **Cephalopod.** Gen. *Turrilites*, sp. *costatus.* From Ventnor.

(31) **Gastropod.** Gen. *Pleurotomaria.*

(32) **Gastropod.** Gen. *Solarium.*

(33) **Gastropod.** A varied group from Headon Hill, Isle of Wight.

(34) **Echinoid.** Gen. *Echinus.* Two specimens.

(35) **Echinoid.** Gen. *Echinocorys.* From Birchington, Kent. Note the calcite deposit in the larger portion and the barytes deposit in the smaller portion of this specimen.

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